ATEWIDE BROWSE EVALUATION

PROJECT REPORT NUMBER TWO

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Editors

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Browse plants sustained the animals hunted by early humans and provided for needs such as clothing demonstrated by this Paiute sagebrush shirt. *Photo courtesy of the Idaho Museum of Natural History.*

Meadow Lark perched in Wyoming big sagebrush. Mike Frisina photo.

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".. herbivory is having a significant negative impact on woody plant growth and survival. The question comes to mind: When will this impact effect wild herbivore populations and, more immediately, birds and small mammals?"

FOREWORD

The 2001 Statewide Browse Evaluation Report gave substance to Montana Department of Fish, Wildlife & Parks' concern about the status of woody vegetation (browse) on big game winter ranges, especially on Wildlife Management Areas. The report data indicated herbivory is having a significant negative impact on woody plant growth and survival. The question comes to mind: "When will this impact effect wild herbivore populations and, more immediately, birds and small mammals?"

The second Statewide Browse Evaluation Report documents continued efforts to quantify the effects of herbivory and, where possible, to correlate changes in browse plant communities with wild, large herbivore populations, primarily moose, elk and mule deer.

In 2006 and 2007, Montana Department of Fish, Wildlife & Parks will attempt to integrate survey and inventory work on vegetation into similar work on game species, with the intent of using habitat condition as a parameter in wildlife management decisions, including hunting season regulations. The browse evaluation method discussed in this report will be one of those tools.

Stephen J. Knapp

Montana Browse Evaluation

Michael R. Frisina

In the mid 1990s some Montana Department of Fish, Wildlife and Parks (MFWP) employees felt that intense browsing by large ungulates may be impacting woody vegetation. In response, the Statewide Browse Evaluation Project was initiated with: "*A stated goal....to evaluate the condition and trend of woody plant species across the state of Montana*" (Knapp and Frisina 2001).

The project objectives included developing a method that MFWP and others could use to evaluate woody vegetation in relation to large herbivore browsing. In 1998 "*Browse Evaluation by Analysis of Growth Form, Volume 1: Methods for evaluating condition and trend*", by Richard B. Keigley and Michael R. Frisina was published. Applications of techniques presented in this book were described in Statewide Browse Project Report No. One-July 2001 (Knapp and Frisina 2001). In our second browse report, we synthesize information collected since then. Many of the papers presented here were previously published in peer reviewed journals. The journal of publication is noted where applicable.

Browse Status

Currently there are 49 established browse evaluation sites across Montana (Table 1, Fig. 1), representing the areas on which our efforts have been concentrated. Data were collected at other sites as well. Sites 1 through 32 represent browse sites at which big game exclosures are present and are locations visited by Thompson (2002) in his evaluation of browse condition and trend on Montana ungulate ranges. Sites 33 through 49 are locations where cooperative research is ongoing between MFWP; United States Geological Survey; Montana State University, Dept. of Animal and Range Sciences; United States Forest Service; Bureau of Land Management; United States Fish and Wildlife Service, and others. Research conducted at several of the locations is reported here.

Our Department's methods for evaluating the influence of browsing by large ungulates on shrubs has extended beyond our agency. Methods described by Keigley and Frisina (1998) are the recommended approach now used by the Beaverhead/Deerlodge National Forest for evaluating browse in southwest Montana (Bengeyfield and Svoboda 1998). Similarly, the Forest Service Pacific Southwest Region has incorporated MFWP browse methods into their approach for annual monitoring of quaking aspen (USDA Forest Service 2004). Browsed plant architectures described by Keigley and Frisina (1998) were included among the methods used by Malheur National Forest personnel in their Middle Fork John Day Range Planning Project Draft Environmental Impact Statement (USDA Forest Service 2005). Keigley and Frisina (1998) is now a standard reference for range survey crews and contract consultants retained by the government of Alberta (Adams 2001). Bitterroot Restoration, Inc. has incorporated Keigley and Frisina (1998) into their riparian and wetland inventory and health assessment (Hansen and Thompson 2003).

Information contained in this and the earlier progress report (Knapp and Frisina 2001) supports the conclusion by Thompson (2002) that "*browsing levels have been and remain a deterrent to development of shrub and aspen communities throughout Montana*".

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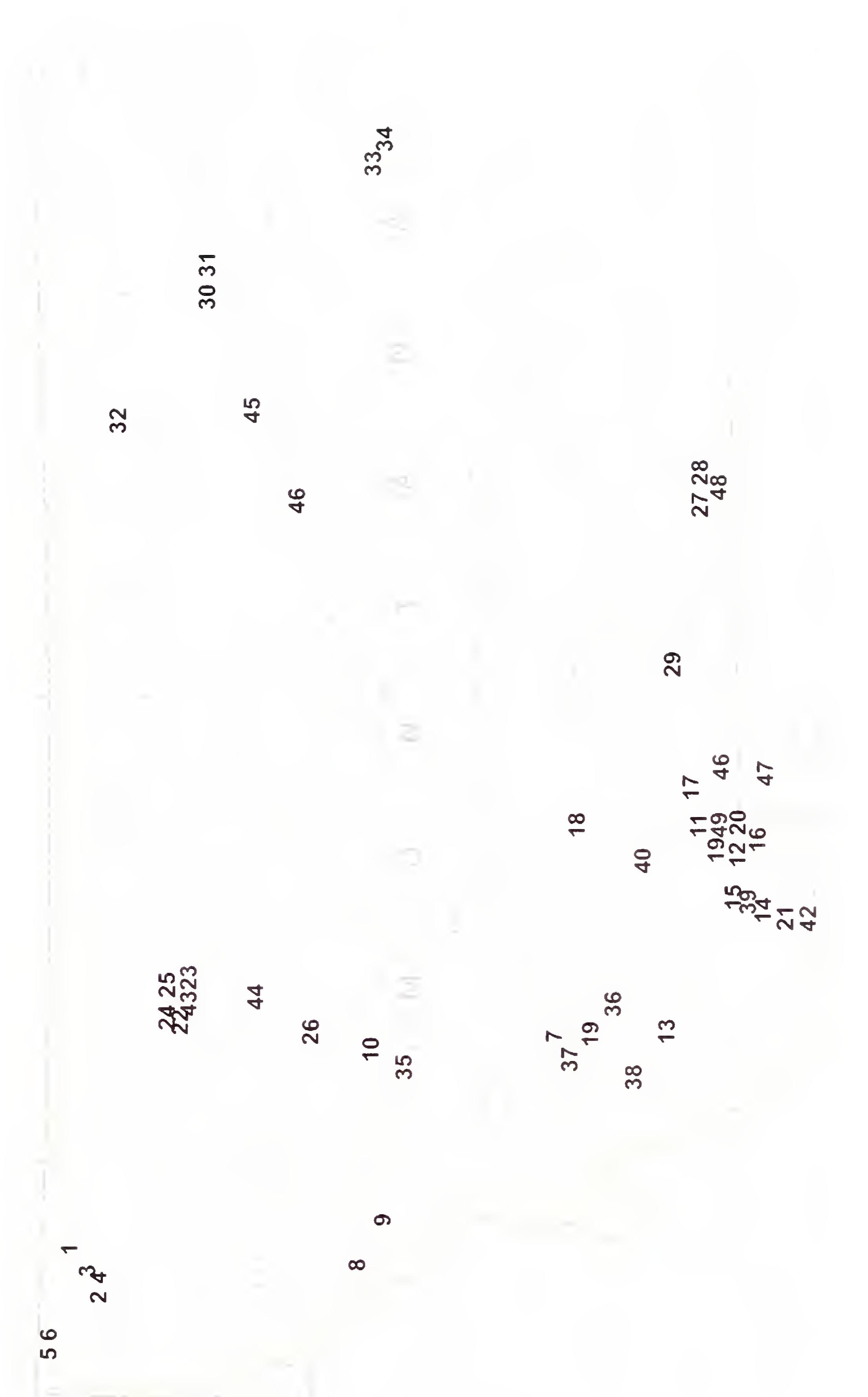

Figure 1. *Location of Montana browse evaluation research sites.*

Table 1. Background information for Montana browse survey study sites.

No.[1]	Name	MFWP Region	Coordinates(Lat./Long.)	Dominant Browse[2] Plants	Dominant Ungulates	Comments
1	Schmitz Mine Exclosure	1	48 48.52N, 114 52.48W	Douglas-fir, service berry, bearberry, snowberry, spiraea, rose, russet buffaloberry, Oregon grape	cattle, elk, mule deer, whitetailed deer	Thompson (2002)
2	Thirsty Lake Exclosure	1	48 50.77N, 115 4.08W	ponderosa pine, Douglas-fir, antelope bitterbrush, Oregon grape, bearberry, snow berry, rose	deer, elk	Thompson (2002)
3	Roberts Mountain Exclosure	1	48 45.16N, 114 55.56W	Douglas-fir, ponderosa pine, bearberry, Oregon grape, service berry, russet buffaloberry	whitetailed deer,	Thompson (2002)
4	Ant Flat Exclosure	1	48 43.56N, 114 52.35W	Douglas-fir, ponderosa pine, serviceberry, russet buffaloberry, bearberry, Oregon grape, snowberry, rose	mule deer, whitetailed deer, cattle	Thompson (2002)
5	Poverty Flat Exclosure	1	48 55.17N, 115 12.35W	serviceberry, russet buffaloberry, antelope bitterbrush, Oregon grape, bearberry	cattle, whitetailed deer, elk	Thompson (2002)
6	Young Cr. Exclosure	1	48 59.48N, 115 11.53W	ponderosa pine, antelope bitterbrush, serviceberry, bearberry, snowberry, rose	whitetailed deer, cattle, elk	Thompson (2002)
7	Dry Cottonwood Exclosure	2	46 12.82N, 112 39.35W	Douglas-fir, Rocky Mountain juniper, antelope bitterbrush, chokecherry,	cattle, elk, mule deer	Thompson (2002)

Table 1. Continued

No.[1]	Name	MFWP Region	Coordinates(Lat./Long.)	Dominant Browse[2] Plants	Dominant Ungulates	Comments
8	Dry Cr. Exclosure	2	47 12.17N, 109 0.93W	Douglas-fir, chokecherry, snowbrush ceanothus, mallow ninebark	elk, mule deer, whitetailed deer	Thompson (2002)
9	Eddy Cr. Exclosure	2	47 0.57N, 114 25.44W	ponderosa pine, serviceberry, bearberry,	elk, mule deer, whitetailed deer	Thompson (2002)
10	Ovando Mtn. Exclosure	2	47 4.72N, 113 3.97W	Rocky mountain maple, service berry, chokecherry, snowbrush ceanothus, mountain ash, pin cherry	elk, mule deer, whitetailed deer	Thompson (2002)
11	Porcupine Cr. Exclosure	3	45 13.62N, 111 14.17W	Douglas-fir, lodgepole pine, mountain big sagebrush, Geyer's willow, aspen	elk, mule deer, moose	Thompson (2002)
12	Snowflake Spring Exclosure	3	45 3.71N, 111 10.05W	Geyer's willow, Booth's willow,	elk, moose	Thompson (2002)
13	Scudder Cr. Exclosure	3	45 18.29N, 113 5.46W	curlleaf mountain mahogany, Rocky Mountain juniper, gray horsebrush, rubber rabbitbrush	mule deer	Thompson (2002)
14	Hyde Cr. Exclosure	3	45 1.01N, 111 42.95W	mountain big sagebrush, gray horsebrush, rubber rabbitbrush, green rabbitbrush, silver sagebrush	cattle, elk, mule deer, antelope	Thompson (2002)
15	Wall Cr. Exclosure	3	44 57.63N, 111 40.79W	aspen	elk, mule deer	Thompson (2002)

Table 1. Continued

No.[1]	Name	MFWP Region	Coordinates(Lat./Long.)	Dominant Browse[2] Plants	Dominant Ungulates	Comments
16	Tepee Cr. Exclosure	3	45 4.22N, 111 9.84W	mountain big sagebrush, gray horsebrush, green rabbitbrush, Oregon grape	elk, mule deer,	Thompson (2002)
17	Garden Cr. Exclosure	3	45 14.45N, 110 50.18W	aspen, willows	elk, mule deer, whitetailed deer	Thompson (2002)
18	Armstrong Exclosure	3	45 54.37N, 111 3.56W	chokecherry, antelope bitterbrush	mule deer	Thompson (2002)
19	Johnson Cr. Exclosure	3	45 50.14N, 113 1.32W	mountain big sagebrush, Wyoming big sagebrush, basin big sagebrush, gray horsebrush, green rabbitbrush	cattle, elk, mule deer	Thompson (2002)
20	Crown Butte Exclosure	3	45 3.87N, 111 8.81W	mountain big sagebrush, aspen, willows	elk	Thompson (2002)
21	Pole Cr. Exclosure	3	44 45.07N, 112 1.63W	willows, silver sagebrush, threetip sagebrush, mountain big sagebrush	cattle, moose, deer, elk, antelope	Thompson (2002)
22	Deer Hill Exclosure	4	48 6.14N, 112 40.66W	horizontal juniper, chokecherry	cattle, mule deer, whitetailed deer	Thompson (2002)
23	Middle Draw Exclosure	4	48 6.14N, 112 40.66W	Bebb willow, aspen, chokecherry	cattle, elk, mule deer, whitetailed deer	Thompson (2002)
24	Lenstra Cr. Exclosure	4	48 6.42N, 112 42.36W	aspen, chokecherry, serviceberry, Rocky Mountain maple	cattle, elk, mule deer, whitetailed deer	Thompson (2002)
25	1500 Acre Exclosure	4	48 4.98N, 112 43.39W	horizontal juniper, aspen	cattle, elk, mule deer, whitetailed deer	Thompson (2002)

Table 1. Continued

No.[1]	Name	MFWP Region	Coordinates(Lat./Long.)	Dominant Browse[2] Plants	Dominant Ungulates	Comments
26	Sun R. Exclosure	4	47 36.55N, 112 40.21W	skunkbrush sumac, chokecherry	elk, mule deer, whitetailed deer	Thompson (2002)
27	Sykes Coulee Exclosure	5	45 1.0 N, 108 17.67W	curlleaf mountain mahogany, Rocky Mountain juniper	feral horses, mule deer	Thompson (2002)
28	Crooked Cr. Exclosure	5	45 5.62N, 108 24.83W	Wyoming big sagebrush, black sagebrush, mountain big sagebrush	cattle, mule deer	Thompson (2002)
29	Picket Pin Exclosure	5	45 26.19N, 109 56.12W	horizontal juniper, mountain big sagebrush,	cattle, mule deer, whitetailed deer, elk	Thompson (2002)
30	South Ranch Exclosure	6	47 50.42N, 106 56.19W	aspen, chokecherry, willows, horizontal juniper, skunkbrush sumac, silver sagebrush	cattle, mule deer, elk	Thompson (2002)
31	Pine Ridge Exclosure	6	47 47.03N, 106 51.67W	ponderosa pine, Wyoming big sagebrush, rubber rabbitbrush, Rocky Mountain juniper	mule deer, elk	Thompson (2002)
32	Cottonwood Exclosure	6	48 28.60N, 107 47.0 W	Wyoming big sagebrush, winter fat	cattle, antelope	Thompson (2002)
33	Hosing Pasture	7	45 5.34N, 105 37.36W	chokecherry, serviceberry	cattle, mule deer, whitetailed deer	Keigley and Ensign (2001), Keigley (2005a)
34	Grue Pasture	7	47 4.15N, 105 32.09W	chokecherry, green ash	cattle, mule deer, whitetailed deer	Within MFWP Cherry Cr. deer trend area.
35	Blackfoot Clearwater WMA	2	47 2.82N, 113 21.96W	aspen	elk, mule deer	

Table 1. Continued.

No.[1]	Name	MFWP Region	Coordinates(Lat./Long.)	Dominant Browse[2] Plants	Dominant Ungulates	Comments
36	Mt. Fleecer WMA	3	45 29N, 112 45W	aspen, big sagebrush, willows, lodgepole pine, Douglas-fir	cattle, elk, mule deer, whitetailed deer, antelope, moose	Keigley and Frisina (2005)
37	Mt. Haggin WMA	3	45 56to58N, 113 1to6W	willows, aspen, bog birch, mountain big sagebrush, low sagebrush	elk, mule deer, whitetailed deer, moose, antelope	Keigely et al. (2001), Keigley et al. (2002a). Keigely et al. (2002b) Keigley et al. (2003) Frisina and Keigley (2004)
38	Steel Cr.	3	45 35.68N, 113 21.77W	willows	elk, moose	Keigley and Gale (2001) Keigley and Frisina (1998)
39	Wall Cr.	3	44 57.49N, 111 40.77W	aspen	elk, moose	
40	Cherry Cr.	3	45 28.56N, 111 32.82W	willows	elk, mule deer, moose	Keigley (2005b)
41	Charles M. Russel National Wildlife Refuge	4-6-7	47 36.31N, 108 39W			Keigley et al. (2005)
42	Red Rock National Wildlife Refuge	3	44 36N, 111 50W	willows	cattle, moose	Keigley and Frisina (2001)
43	Theodore Roosevelt Memorial Ranch	4	48 7.63N, 112 41.5W	chokecherry, aspen, willows, serviceberry, red osier dogwood, horizontal juniper		Keigley and Olson (2001)
44	Ear Mtn. WMA	4		lodgepole pine, Douglas-fir, aspen, skunkbrush sumac, chokecherry, wild rose, shrubby cinquefoil, Bebb willow	cattle, elk, mule deer, bighorn sheep	Frisina and Kujala (2001)

Table 1. Continued.

No.[1]	Name	MFWP Region	Coordinates(Lat./Long.)	Dominant Browse[2] Plants	Dominant Ungulates	Comments
45	Cowell Conservation Easement	6	47N, 107W	Wyoming big sagebrush, chokecherry, buffalo berry	elk, mule deer	Frisina and Sullivan (2005)
46	Gardiner Basin	3	45 6to7N, 110 67to73W (45.05613N, 110.73212W, 45.06978N, 110.66936W)	mountain big sagebrush, Wyoming big sagebrush, black sagebrush	mule deer, elk, bison	Wambolt et al. (2006)
47	YNP Sheepeater	3	44 9N, 110 73W (44.88783N, 110.73343W)	mountain big sagebrush	elk, bison, mule deer	Wambolt et al. (2006)
48	Pryor Mountain	5	44N, 110W (44.88783N, 110.73343W)	Wyoming big sagebrush, black sagebrush	Rocky Mountain bighorn sheep, mule deer, feral horses	Wambolt et al. (2006)
49	Porcupine WMA	3	45 13.65N, 111 14.33W	mountain big sagebrush, basin big sagebrush	mule deer, elk	

[1]Refer to Fig. 1.
[2]Browse species studied or mentioned in the referenced publication.

Notes

Status of Ungulate Exclosures in Montana

Scott Thompson and Stephen J. Knapp

Introduction

Resource managers have long realized the need to study the impact and extent of ungulate use of plant communities. During the period from 1930-1950, the effect of past abuses by livestock, big game over-populations and drought were realized on many ranges in Montana (Mussehl and Howell 1971). Beginning in the 1930's, ungulate proof exclosures were constructed on many big game winter ranges and other areas of concern to evaluate the influence of ungulates on browse species and other forages (Fig. 1). Many of these exclosures

Figure 1. Sign at the Ovando Mountain big game exclosure, 1960. This exclosure is currently functioning.

have been in place for more than 50 years and provide a unique opportunity to evaluate the long-term effect of ungulates on their habitats. Many of these exclosures remain functional, but are deteriorating and nearing the end of their useful life. The purpose of this paper is to describe the functioning condition of exclosures in Montana. Furthermore, exclosures in need of repair will be identified and prioritized.

Exclosure Descriptions

Daubenmire (1940) described an exclosure as any experimental area, which is protected from the activities of a particular class of animal by a barrier such as a fence or screen. Exclosures were typically designed according to animals using the area. A total or big game exclosure includes an area enclosed by an 8 to 10 ft. tall fence preventing access of all ungulates. A 3-phase exclosure system was designed to differentiate the impact of wild ungulates and domestic ungulates. This system includes a big game exclosure and an area enclosed by a 3 to 4 ft. tall fence restricting access of domestic ungulates but allowing wild ungulates to enter (livestock exclosure, Fig. 2). The area outside both exclosure receives use by both ungulate classes. Other variations include antelope/livestock, rodent, and rabbit exclosures.

Big game exclosures were typically constructed with 10-12 ft. wood corner and brace posts, 10 ft. wood or metal span posts, 6 ft. woven wire and 2-3 strands of barbed wire placed above the woven wire (Fig. 3). Some exclosures designs used wood rails instead of barbed wire above the woven wire (Fig. 4). Due to the common use of wood fence posts exclosure fences are vulnerable to rot and fire.

Exclosure Inventory

An inventory of exclosures in Montana was done between 2000 and 2002 as a part of a browse evaluation study (Thompson 2002). A list of 86 big game exclosures compiled by Dick Mackie in 1975 provided the basis for locating exclosures. Forty-nine of the original 86 were accounted for (Table 1). An additional 13 exclosures built after 1975 were located. Exclosure locations are shown in Figure 5.

At each exclosure, the area inside was searched to determine use by ungulates. The condition of the exclosure and need for repair was determined by the extent of damage to the fence, how recent the fence was breached and degree of ungulate use of the area (Table 1). Priority of repair is based on the following criteria:

1- Fence recently breached, area heavily used by ungulates, evidence of recent use inside exclosure
2- Fence nearly breached, area heavily used by ungulates.
3- Area heavily used by ungulates, fence continually needing maintenance
4- Old breach to fence, recent and old use inside exclosure

Region 1

Twelve exclosures were located in Region 1. Exclosures were constructed between 1934 and 1963. Major browse species in these exclosures includes serviceberry, bitterbrush, bearberry, Oregon grape, and Rocky Mountain maple. Six of the twelve original exclosures are no longer in existence. Of the remaining six, four are functioning properly and two are in need of repair. Exclosures

Figure 2. Picket Pin 3-phase exclosure in Region 5. Big game exclosure is located in the center and livestock exclosure left. This exclosure is functioning, but receives heavy use by wildlife and livestock.

Figure 3. Big game exclosure fence at Dry Cottonwood Creek in Region 2. Exclosure fence height is approximately 10 feet.

Figure 4. Armstrong big game exclosure in Region 3. Exclosure is functioning, but is nearly breached.

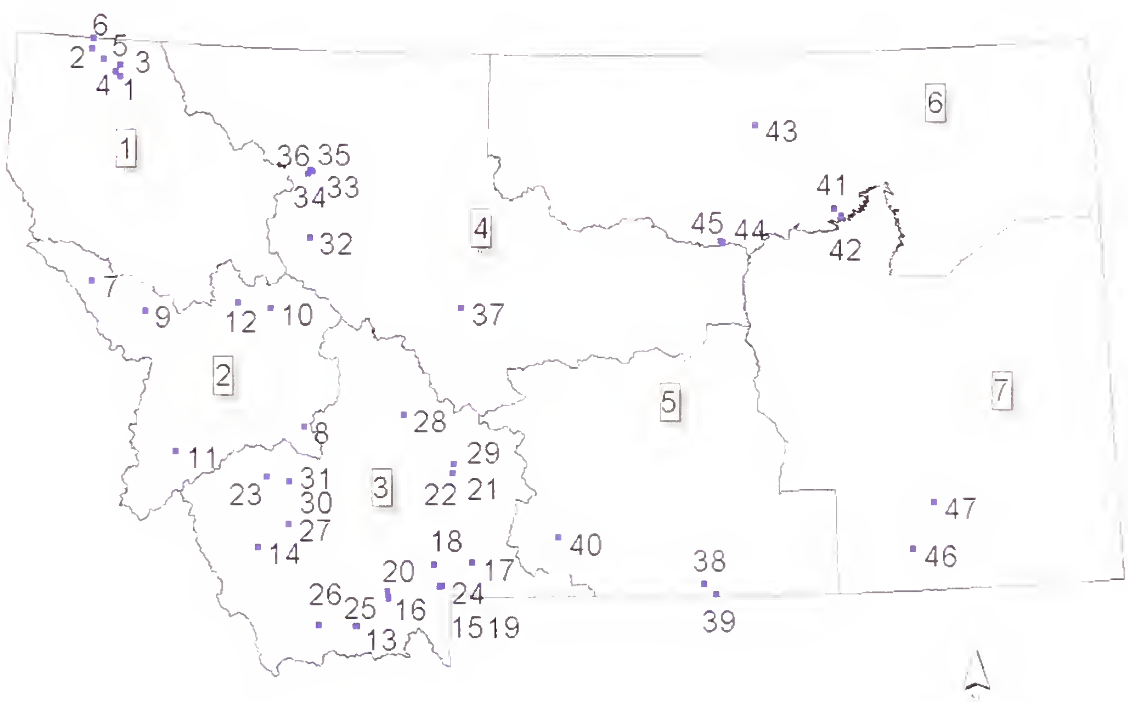

Figure 5. Locations of big game and livestock exclosures in Montana by MFWP region. Exclosure numbers correspond with site numbers in Table 1.

Tabler 1. Big game and livestock exclosures in Montana.

Exclosure	Site #	Year built	Type	Lat	Long	Condition	Major Browse Species	Repair Priority
Region 1								
Ant Flat	1	1962	G/L	48 725916	-114 8735	MF	AMAL	1
Dodge-Poverty	2	1958	G/L	48 919444	-115 206888	MF	PUTR-AMAL	1
Schmitz Mine	3	1962	G	48 808611	-114 875722	F	AMAL	
Roberts Mountain	4	1962	G	48 752583	-114 927027	F	AMAL-ARUV-BERE	
Thirsty Lake	5	1962	G	48 846	-115 068916	F	PUTR-BERE	
Youngs Cr	6	1958	G/L	48 991333	-115 193138	F	PUTR	
Mud L Ten Mile, Rondo Cripple Horse Big Cr, Whitefish L		1934-1963		NA	NA	D		
Region 2								
Dry Cr	7	1954	G	47 202833	-115 016138	F	AMAL	
Dry Cottonwood	8	1961	G/L	46 213555	-112 65675	F	PUTR	
Eddy Cr	9	1959	G	47 009333	-114 424888	F	AMAL-ARUV	
Ovando Mountain	10	1957	G	47 078611	-113 067083	F	AMAL-ACGL-PRVI	
Rye Cr /Spring Gulch	11	1954	G	45 983416	-114 002888	NF	PUTR	4
Salmon Lake	12	1951	G	47 110527	-113 425583	NF	AMAL	4
Drexel Patrick Cr		1959		NA	NA	D		
Region 3								
Lost Cr	13	1953	G	44 749138	-112 0135	MF	CELE	2
Scudder Cr	14	1953	G	45 304805	-113 091888	F	CELE-ARTR	3
Tepee Cr	15	1991	G	45 070305	-111 164833	MF	ARTR-SAGE-POTR	1
Wall Cr Aspen	16	1990	G	44 960277	-111 693305	MF	POTR	2
Garden Cr	17	1990	G	45 240833	-110 837027	MF	POTR	2
Porcupine Cr	18	1945	G	45 225805	-111 2355	F	ARTR-SAGE-POTR	3
Snowflake Springs	19	1948	G	45 061777	-111 168361	F	SABO	
Hyde Cr	20	Unknown	G	45 016722	-111 716722	F	ARTR-ARCA	
Armstrong 1	21	1955	G	45 906083	-111 060194	F	PUTR-PRVI	2
Armstrong 2	22	1955	G	45 905555	-111 062833	F	PUTR	2
Johnson Cr	23	1967	G/L	45 835555	-113 022916	F	ARTR	
Crown Butte	24	1945	G	45 064472	-111 147611	F	SABO-PUTR	3
Pole Cr	25	1991	G	44 751166	-112 027972	F	SABO-SAGE	
Basin Cr	26	Unknown	G	44 752527	-112 407194	F	SALIX	
Long Cr	27	1991	G	45 491194	-112 772222	NF	SABO-SAGE	4
Limestone Hills	28	1963	G	46 31925	-111 595861	NF	CELE	4
Pass Cr	29	1963	G	45 974611	-111 054777	F	ARTR-AMAL	
Fleecer Mountain 1	30	1989	G	45 807277	-112 775055	F	TECA	
Fleecer Mountain 2	31	1989	G	45 808055	-112 782666	F	SALIX	
Region 4								
Burdoff Cr (Sun R)	32	1967	G	47 609194	-112 671027	MF	RHTR-PRVI	2
Deer Hill	33	1987	G/L	48 102111	-112 679305	F	JUHO-PRVI	3
Middle Draw	34	1987	G/L	48 102305	-112 678611	F	SABE-POTR-PRVI	3
Lenstra Cr	35	1987	G/L	48 106888	-112 706916	F	SABE-POTR	3
1500 Acre	36	1987	G/L	48 083027	-112 724083	F	JUHO-POTR	3
Lick Cr	37	1959	G/L	47 12138	-111 00224	F	JUCO	
Hunter's Gulch		1960		NA	NA	D		
Region 5								
Crooked Cr	38	1962	G/L	45 093583	-108 414527	MF	ARTR-ARNO	1
Sykes Coulee	39	1964	G/L	45 016611	-108 295138	F	CELE	
Picket Pin Cr	40	1962	G/L	45 436361	-109 936027	F	JUHO	3
W Fork Rock Cr Red Lodge Cr Main Boulder		1960-1962		NA	NA	D		
Region 6								
South Ranch	41	1987	G/L	47 840333	-106 937166	F	PRVI-POTR-SALIX	3
Pine Ridge	42	1970	G	47 783777	-106 861805	F	ARTR-CHNA	
Cottonwood	43	1967	G	48 476638	-107 784027	F	ARTR-CELA	
Nichols Coulee	44	1965	G/L	47 611444	-108 165888	F	ARTR-ATGA	
Nichols Coulee	45	1965	G/L	47 618000	-108 196222	F	ARCA-SAVE	
Region 7								
Cow Cr	46	1961	G/L	45 303416	-106 212888	NF	RHTR-ARCA	4
Little Pumpkin	47	1961	G/L	45 640222	-105 976055	NF	PRVI	4
McClary, Capitol Rock Upper Home Cr		1959-1960		NA	NA	D		

G- Big Game Exclosure only G/L- Big Game and Livestock Exclosures

Exclosure Fence Condition F- Functioning MF- Mostly Functioning, NF- Not Functioning, D- Destroyed

Acgl- Rocky Mountain Maple *Amal*- serviceberry *Arca*- silver sagebrush, *Arno*- black sagebrush, *Artr*- big sagebrush *Aruv*- bearberry *Atga*- saltbrush *Bere*- Oregon grape *Cela*- winterfat *Cele*- curl-leaf mountain mahogany *Chna*- rubber rabbitbrush, *Juco*- common juniper *Juho*- horizontal juniper *Potr*- aspen, *Prvi*- chokecherry *Putr*- bitterbrush, *Rhtr*- skunkbrush sumac *Salix*- willow sp *Sabe*- Bebb willow, *Sabo*- Booth's willow, *Sage*- Geyer's willow *Save*- greasewood, *Teca*- gray horshbrush

and repairs needed are:

The Ant Flat exclosure was partially burned several years ago. Repairs would include replacing 15 to 20 -10 ft. wood posts and stretching the wire.

The Dodge/Poverty exclosure has recently been breached by a down tree. Repairs would include removal of the tree and replacing five 10 ft. wood posts.

Region 2

Six exclosures were found in Region 2. Exclosures were built between 1951 and 1961. Major browse species in these exclosures includes serviceberry, bitterbrush, bearberry, Rocky Mountain maple and chokecherry. Four of the six exclosures are functioning properly and two are in need of rebuilding. Two additional exclosures are thought to be destroyed (Drexel and Patrick Cr.). Exclosures and repairs needed are:

Rye Cr./Spring Gulch exclosure has burnt and received use by browsing animals inside. Repairs would entail replacing half of the wooden posts and wire.

Salmon Lake exclosure has fallen down over the years and would require extensive repairs. More than half of the wooden posts have fallen down and new woven wire would be needed.

Nineteen exclosures were found in Region 3. Exclosures were built between 1945 and 1991. Major browse species found in these exclosures includes big sagebrush, silver sagebrush, curl-leaf mountain mahogany, gray horsebrush, bitterbrush, chokecherry, serviceberry, willow species, and aspen. Thirteen of the nineteen exclosures located are functioning properly, four are mostly functioning and two are no longer functioning. Exclosures and repairs needed include:

Wall Cr. exclosure was built in an aspen community. Big game animals are gaining access to the exclosure, presumably in the winter. Access is likely on the north side where snow drifts up and the fence is sagging. Repairs would include reinforcing the north side and extending the north fence up 3 feet.

Tepee Cr. exclosure is located on an important elk winter range consisting of a big sagebrush community. Recent breaches were found in the southeast corner of the exclosure. Repairs would include replacing several steel posts and replacing 50 ft. of wire.

Garden Cr. exclosure is located in an aspen community on the Dome Mountain WMA. Continual falling of aspen trees as degraded most of the wire. Additionally, cuts to the fence have been found. Repairs include stretching wire on all sides of exclosure and cutting downed trees.

Lost Cr. exclosure is located on a hillside dominated by curl-leaf mountain mahogany. This exclosure is located on a mule deer trend area. The fence is mostly in good shape with some recent breaches. Repairs would include replacing several metal fence posts and stretching the wire.

Limestone Hills exclosure is located on curl-leaf mountain mahogany community used extensively by mule deer. This exclosure is mostly intact, but big game animals have had access to the exclosure for some time. The exclosure fences appear to be too short and would need to be extended up another 3 feet to be effective.

Region 4

Seven exclosure were found in Region 4. Exclosures were built between 1960 and 1987. Major browse species in the exclosures include horizontal juniper, bitterbrush, skunkbrush sumac, chokecherry, willow species and aspen. Five exclosures are functioning, one is in need of repair, and one was destroyed (Hunters Gulch). Exclosure and repairs needed include:

Burdoff Cr. is on the Sun River WMA. The exclosure receives heavy use by ungulates. Repairs needed include replacing 5-10 wooden posts, stretching wire, and extending the exclosure fence up 2-3 feet.

Region 5

Four exclosures were found in Region 5. Exclosures were built between 1960 and 1964. Browse species occurring in these exclosures includes big sagebrush, black sagebrush, curl-leaf mountain mahogany, horizontal juniper, skunkbrush sumac, and chokecherry. Two exclosures are functioning properly, one is in need of repair and one was destroyed (Main Boulder). Two additional exclosures are thought to be destroyed (W. Fork Rock Cr. and Red Lodge Cr.) Exclosures and repairs needed include:

Crooked Cr. exclosure in the Pryor Mountains is located on a sagebrush community. The north fenceline has fallen down and would require replacing several posts and stretching the wire.

Region 6

Five exclosure were located in Region 6. Exclosures were built between 1965 and 1987. The five exclosures are all functioning and do not require immediate repairs. An additional exclosure (Pronghorn) north of Malta was not found and is presumed destroyed.

Region 7

Five exclosure were accounted for in Region 7. Two exclosures in the Long Pines have been destroyed in forest fires. The remaining three exclosures located in the Ashland Forest are not functioning or are destroyed. Exclosures and repairs needed include:

Cow Cr. exclosure has recently been burned. Repairs would entail replacing many of the wooden posts and replacing wire on half of the fence.

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Assessing Browse Trend at the Landscape Level

Part 1: Preliminary Steps and Field Survey

Richard B. Keigley, Michael R. Frisina, and Craig W. Fager

Woody plants are an important component of rangeland habitat, providing food and shelter for animals that range in size from moose to warblers to insects. Because of this importance, land managers are paying increased attention to browse trends. In this two-part paper, we describe how browse trend is assessed at the Mt. Haggin Wildlife Management Area in southwestern Montana.

Located south of Anaconda, Montana (Fig. 1), winters are extremely cold and windy at the Mount Haggin Wildlife Management Area. The annual precipitation is about 20 inches, much of which occurs as snow

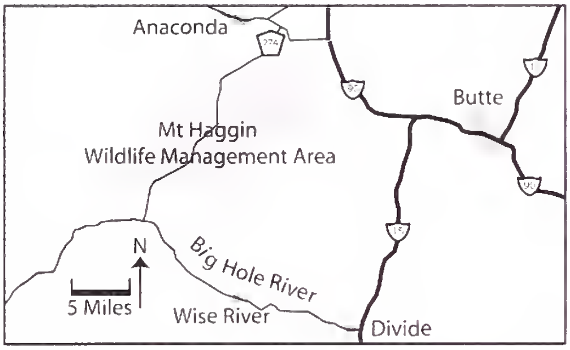

Fig. 1. *Map of study area.*

There are resident and transient ungulate populations. Moose is the only ungulate species present in all months. Elk, mule deer, and pronghorn antelope are present much of the year, but cannot contend with the deep snowcover that exists during mid-winter. Whitetail deer and cattle are present during the warm season. Cattle are managed under a three-pasture rest-rotation grazing system.

During the fall, a significant transient moose population is present. As snowcover deepens in the Pintler Mountains to the west, moose migrate from those mountains and stage in the area before migrating to lower elevation winter range in the Big Hole Valley. Over the past three decades, the moose population has increased. Censuses by Montana Fish, Wildlife & Parks in the 1970s reported an average of 9 animals; in 1980s, an average of 19 animals was reported; in the 1990s, an average of 39 was reported.

Willows present in the study area include Geyer, Drummond, Booth, planeleaf, Scouler, and Wolfs willow (Fig. 2). The riparian species are found in

Fig. 2. *Willow community provides critical habitat for wildlife.*

two general kinds of valley bottoms. At the lower end of drainages, the valleys tend to be wide and flat-bottomed, and locally bordered by glacial moraines. Within some of the flat-valley-bottom areas, willow communities are confined to the corridor immediately adjacent to relic or current stream courses. At other locations, ponding caused by beaver dams, has allowed willow communities to spread across a broad area. At the upper end of the drainage, willows are confined within relatively narrow, v-shaped valleys. In the upper drainages, conifers often are present within the willow community.

Willows are currently heavily browsed (Fig. 3), but there is evidence that browsing pressure was lower in the past. Heavily-browsed 14-inch-tall plants grow in close proximity to 16-foot-tall plants, the tallest stems of which are unbrowsed (Fig. 4). The 16-foot-tall stems are older than the 14-inch-tall stems, and apparently grew through the browse zone when browsing pressure was lower than its current level. An increase in browsing pressure would be consistent with the increase in the moose population that occurred over the past 3 decades.

Our trend assessment involved five steps. Steps 1 through 3 were preliminary to the actual assessment of trend. Actual trend assessment occurred during steps 4 and 5.

Step 1: Identify relevant management objectives

The management of the browse resource was linked to area-wide management objectives. Two such objectives were deemed especially important. First, the area was purchased to provide winter

Fig. 3. *Heavy browsing produces clusters of twigs at the end of stems. A substantial portion of this shrub is dead.*

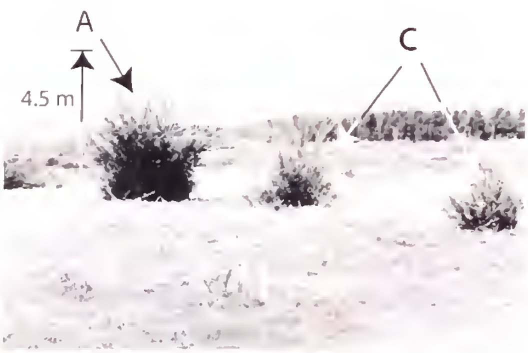

Fig. 4. *A qualitative history of browsing can be interpreted by observing the relationship between plant height and plant age. In this case, an increase in browsing pressure has prevented young willows from attaining full stature.*

range for big game. To serve as winter range, browse plants must be available for ungulate use under snowcover that ranges from negligible early in the winter season, to snow that lies more than 3- to 4-feet deep in mid-winter. In addition, Montana Fish, Wildlife & Parks is committed to providing habitat for a variety of game and nongame wildlife; for example, Mt. Haggin Wildlife Management Area provides nesting habitat for sandhill cranes and neotropical migrants. Accomplishing these management objectives requires the presence of appropriately-sized woody plants. At Mt. Haggin, willows range in height from very small, young plants, to older plants more than 16-feet tall. The preservation of this diversity in plant heights is essential to meeting the management objectives.

Formally stated, the management objective is: *Plants of diverse heights will be present, ranging to the full height potential as determined by local environmental conditions.*

Common and scientific names of species.

Wild Ungulates	
[illegible]	[illegible]
American pronghorn antelope	[illegible]
Rocky Mountain elk	[illegible]
Rocky Mountain mule deer	[illegible]
White-tailed deer	[illegible]
Plants	
dogwood	[illegible]
spruce	[illegible]
Booth's willow	[illegible]
[illegible] willow	[illegible]
[illegible] willow	[illegible]
[illegible] willow	[illegible]
[illegible] willow	[illegible]
[illegible]	[illegible]

Full-statured plant stems (say those that grew to 16-feet tall) have a finite lifespan. If full-statured stems are to persist in a community, young stems must grow to full stature to replace those that die of old age. Heavy browsing can prevent young stems from growing through the browse zone. Continued long enough, heavy browsing can lead to the elimination of entire browse plant communities.

To maintain a plant community of varied heights, browsing must be light enough to allow young stems to grow through the browse zone and attain full stature. We used three methods to examine the fate of stems as they attempted to grow through the browse zone (architecture, stem height, and growth rate). Because full-statured stems are relatively long-lived, it is not necessary that *all* young stems grow to full stature—just *some*. Thus we look for evidence that browsing has prevented *all* young stems from growing tall.

Step 2: Indicator species

We focused on a single indicator species. That species should have two characteristics. First, it should be among those preferred by ungulates. A highly-preferred species (such as dogwood) is a more sensitive indicator of browse impacts than less-preferred species (such as spruce). Second, the indicator plants should be widely distributed across the managed area. From this distribution, managers can determine how browsing level varies across the landscape. We selected Geyer willow as the indicator species.

We assume that the fate of other browse species is indicated by the trend of Geyer willow. If Geyer willow is in decline, the decline of more-highly preferred species would already have occurred. As the amount of available Geyer willow diminishes, less-highly preferred browse species will begin to decline.

Step 3: Delineating the distribution of the indicator species

We prepared a map on which we estimated the total distribution of Geyer willow in the study area

(Fig. 5). We used the map to prioritize the subse-

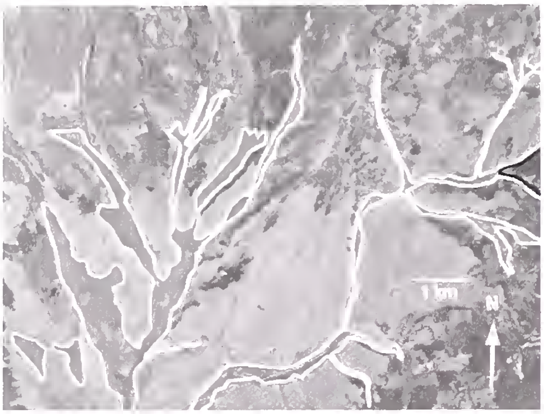

Fig. 5. *Map showing distribution of Geyer willow. This map served as the basis for selecting areas for surveying and monitoring.*

quent steps of field surveying and monitoring. The map was based on a combination of site visits and by examining willow canopy cover on 1:12,000 aerial photographs. From site visits, we determined that Geyer willow extended across the full elevation range included in the study area. This distribution implied that, if any riparian willows were present in an area, Geyer willow plants would likely be included.

Because the map was to be used primarily for prioritizing future work, it was not necessary that the willow community boundaries be precisely drawn. In our case, high quality aerial photographs made the job relatively simple. This step could also be accomplished using images downloaded from the Internet or by delineating the approximate community boundaries on a topographic map.

Assessing trend—some general comments

Trend was assessed using two approaches: field surveys and monitoring. During surveys, emphasis was placed on rapidly covering a broad geographic area. During monitoring, more-detailed data were collected from fixed locations; those same locations will be resampled periodically.

In the course of assessing trend, three different questions were addressed:

1. In recent years, have plants been able to grow through the browse zone? (This question is addressed in field surveys by examination of plant architectures.)
2. Over the long term, are plants growing taller? (This question is addressed during monitoring by comparing the height of live stems to the height of stems killed by browsing.)
3. Do plant stems grow fast enough to grow out of ungulate reach before they die? (This question was addressed during monitoring by determining stem lifespan and by measurement of growth rate.)

The data collected during surveys and monitoring complement one another; managers can emphasize one type of data over another to suit their needs. If it is most important to determine how browsing level might vary across the landscape, the manager can emphasize the survey component. Alternatively, managers wishing to track short-term changes in browsing impacts can do so with the type of data collected during monitoring.

Step 4: Trend assessment by field surveys

Field surveys document two aspects: a) browsing level, and b) plant height. Browsing level is an indicator of trend. Plant height indicates the availability of browse during winter. And if the community is in decline, plant height provides a rough indication of persistence; tall willow plants, with some stems out of ungulate reach, appear to live longer than shorter willows in which all terminal leaders are heavily browsed.

Below, we describe two field surveys, one conducted on a segment of Sullivan Creek, the other on a segment of Deep Creek. Both areas contain willows that range in height from very short, young plants (e.g., 8 inches) to older plants that are more than 16-feet tall.

Browsing level. Two levels of browsing are distinguished: a) intense, and b) light-to-moderate. In Keigley and Frisina (1998) we present specific rules for determining if a stem is intensely browsed. Intense browsing occurs when a complete annual segment is killed; current-year-growth develops from a segment older than the previous-year's-growth. Under light-to-moderate browsing, current-year-growth consistently develops from the previous-year's-growth. These rules apply at the stem level.

At the whole-plant level, browsing level affects plant architecture (growth form). We have identified four architecture-types that correspond to four browsing regimes (Fig. 6). The architectures are produced during the period of time that the terminal leader grows within the browse zone. They are:

a) Uninterrupted-growth-type architecture (produced under light-to-moderate browsing conditions),

b) Arrested-type architecture (produced by intense browsing),

c) Retrogressed-type architecture (produced by a change from light-to-moderate browsing to intense browsing), and

d) Released-type architecture (produced by a change from intense browsing to light-to-moderate

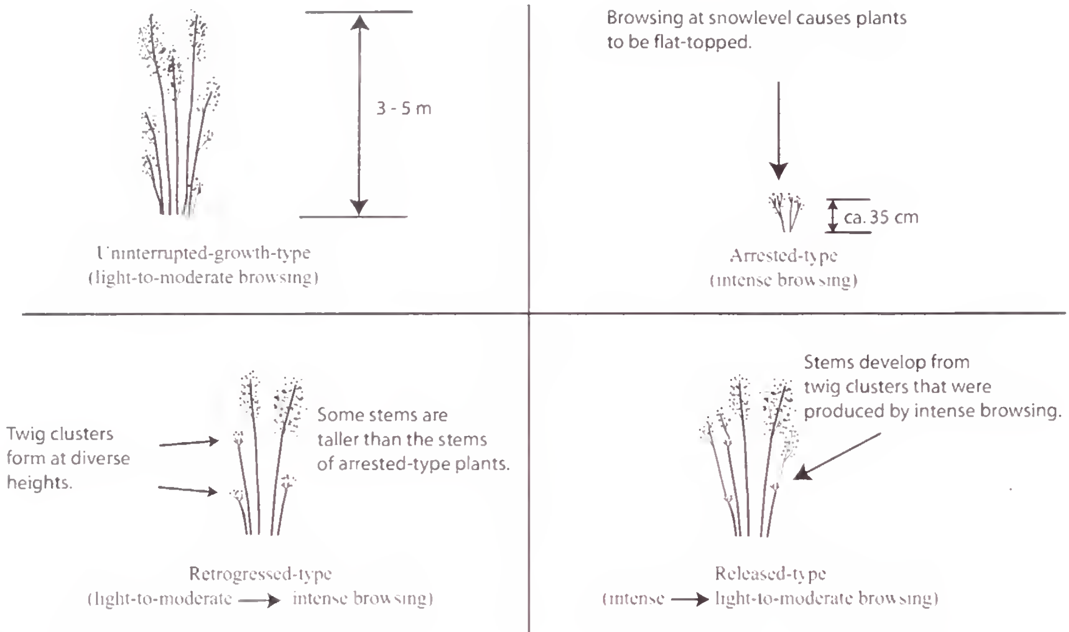

Fig. 6. ***Browsing-related architectures.***

browsing).

Because these architectures are mainly produced when the plant is young, one can interpret the browsing history of a site by examining plants of different age.

To assess trend, we examined the architecture of plants with terminal leaders in the browse zone. At Mt. Haggin, the browse zone extends from a lower limit of about 8 inches (20 cm) above ground level to an upper limit of about 8 feet (2.5 m). Plants are apparently browsed at 8 inches early in the winter season as snow begins to accumulate. The upper limit of the browse zone is controlled by ungulate reach. Stems greater than about 5 feet (1.5 m) may be out of direct reach of deer and livestock; elk and moose can reach upwards of 8 feet (2.5 m). Browsing at heights greater than those upper limits can occur when ungulates stand on crusted snow, stand on hind legs, or bend stems to the ground.

Measurement Units

Our methods involve relationships between small lengths (stem growth rates that are sometimes less than one inch per year) and large lengths (plant heights greater than 8 feet). Because calculations involving inches and feet are cumbersom, field measurements were made in metric units.

Throughout the text, length measurements are described in English units, with values often rounded to the nearest inch or foot. The measured metric units are presented in parentheses.

We characterized the level of browsing by examining the architecture of plants in which the base of the terminal leader was between 30 and 60 inches (75-150 cm) tall. Plants in this height range likely were exposed to browsing during recent winters.

We distinguished between two situations: a) *all* plants exposed to browsing have arrested- or retrogressed-type architecture (mapping unit: "100% intensely browsed"), and b) *some* plants exposed to browsing have uninterrupted-growth- or released-type architecture (mapping unit: "<100% intensely browsed"). In the case where all plants have arrested- or retrogressed-type architecture, it is probable that no young plants will attain their potential height. In the second case, some plants apparently will attain full stature, and the desired condition will be maintained or attained.

As we traversed the field survey area, we delineated the willow area on an aerial photograph. We partitioned that area into the two mapping units described above. As we moved through an area, we sought out plants that might have uninterrupted-growth- or released-type architecture. When such plants were found, we tried to determine why they had escaped browsing. If a plant was deemed to have escaped browsing because of local protection, we discounted the architecture of that plant as an indicator of area-wide browsing pressure. Local protection of a young plant might occur when a taller neighbor inhibits ungulate access, either directly or by creating a deep snowdrift. When these circumstances were confined to a few square meters, we assumed that the protective effect was temporary.

Plant height. Plant height was documented by narrative description in the Sullivan Creek survey and by mapping in the Deep Creek survey. In the Sullivan Creek survey, we described the general

circumstances under which willows greater than 10-feet (3-m) tall were found.

In the Deep Creek survey, we distinguished between three plant-height categories: a) Short (the plant is < 20-inches (50-cm) tall, symbolized by "S"), b) Intermediate (between 20-inches (50-cm) and 9.8-feet (3-m) tall, symbolized by "I"), and Tall (> 9.8-feet (3-m tall), symbolized by "T"). Plant-community height characteristics were described using combinations of the three categories: S, I, T, SI, ST, IT, and SIT. For example, a community composed of willows less than 20-inches (50-cm) tall and willows greater than 9.8-feet (3-m) tall would be designated ST. A site that has experienced protracted intense browsing may be composed entirely of plants in the S category. During the winter, plants in the S category often are buried by snow and unavailable to ungulates. Plants in the I and T categories are a source of browse under diverse snowcover conditions.

Category T was distinguished because stems greater than 3-m tall often escape browsing. The presence of tall terminal leaders might allow a shrub to persist longer than shrubs that solely consist of shorter terminal leaders that are all heavily browsed. As in the mapping of browsing level, the total willow area was delineated on an aerial photograph and partitioned—as we traveled across the area—into the 7 mapping units listed above.

Deep Creek field survey. The surveyed segment was about 0.6 miles (1 km) long; willow covered 270 acres (110 ha) (Fig. 7). The entire area was classified as 100% intensely browsed. As above, the few uninterrupted-growth type plants were growing in vicinity of taller, heavily browsed, neighbors. We assumed the mechanical protection was temporary.

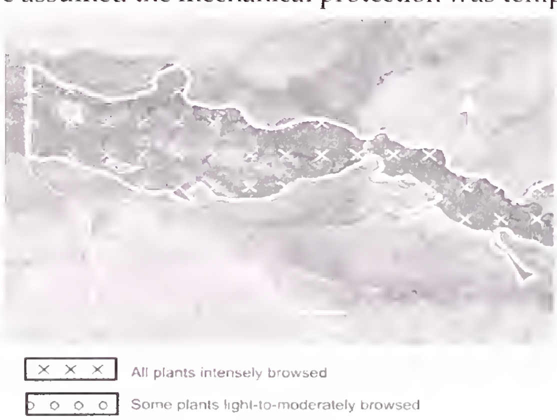

Fig. 7. *Browsing intensity on Deep Creek segment of field survey. The entire area was 100% intensely browsed.*

Stands that included willows greater than 9.8-m (3-m) tall constituted 33% of the total willow area of 89 acres (36 ha) (Fig. 8). The remainder of the area

Fig. 8. *Willow height at Deep Creek segment.*

(i.e., 67%) consisted of willows that ranged in height from ca. 8 inches to 8 feet (20-250 cm) tall. While we currently have no basis for quantitatively predicting the rate of decline, we do know that 67% of the willow area is susceptible to a relatively rapid rate of decline.

Sullivan Creek field survey. The surveyed segment of Sullivan Creek was about 2.2 miles (3.5 km) long; willow covered 570 acres (230 ha) (Fig. 9). The entire area was classified as 100% intensely browsed. Uninterrupted-growth-type plants were uncommon. In each case, we could identify how the plant was mechanically protected from browsing. If current browsing pressure continues, the protection will be temporary. As the plants adjacent to the uninterrupted-growth-type plants die, moose will focus on the remaining live plants.

Fig. 9. *Browsing intensity on Sullivan Creek segment of field survey. The entire area was 100%% intensely browsed.*

Willows greater than 9.8 feet (3 m) tall grow in linear zones along current and relict watercourses.

Linear zones of tall willows are also associated with beaver dams. Many of the ponds have drained, allowing willows to become established there; these willows range in height from about 8 inches to 7 feet (20-200 cm) tall. Willows could have become established on the beaver dams when the ponds were still filled with water, so in part, willows growing on the dams may be taller because they are older than willows growing on the former pond areas. In part, the difference in height might be due to heavier browsing of willows growing in the pond areas. A dendrochronologic analysis of stems indicates that browsing pressure increased in the mid-1980s. Willows established since the 1980s would have experienced intense browsing while the tallest terminal leaders were within the browse zone. There is extensive mortality of shorter willows.

Summary of Part 1

We described above how plant architectures can be used to assess browse trend across large geographic areas. However, the statistical analysis of the architecture data is limited. In Part 2 of this paper we describe how browse trend was further assessed using quantitative data that were periodically collected at fixed sites. We refer to that phase of trend assessment as "monitoring."

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Assessing Browse Trend at the Landscape Level
Part 2: Monitoring

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In Part 1 (in this issue of *Rangelands*), we assessed browse trend across a wide geographic area of Mt. Haggin Wildlife Management Area by conducting surveys of browsing-related architectures. Those data were qualitative. Below we describe the periodic collection of quantitative data from permanently marked locations; we refer to this phase of the trend assessment program as "monitoring." Trend was monitored by three methods:

1. Repeat photography.
2. Comparison of the height of live stems with the height of stems killed by browsing (LD Index).
3. Net annual stem growth rate ($NAGR_{L3}$).

The photography provides an assessment of trend from the comparison of photographs taken at intervals of a few years. The LD Index and $NAGR_{L3}$ measurements provide an immediate assessment of trend.

Establishment of permanent stations. Three considerations entered into the location of monitoring stations. Based on observation of moose habits, the stations were located in areas heavily used by moose. The stations were dispersed across the area in which Geyer willow occurs. The sites are accessible with relatively little effort.

Each station's location was documented in 6 ways: a) small-scale map, b) narrative description, c) large-scale sketch map, d) GPS coordinates, e) photographs of surrounding area, and f) a steel fence post. The small-scale map and narrative description should locate the station to within about a hundred meters. The large-scale sketch map, GPS coordinates, and area photographs should lead a person directly to the steel post.

Four monitoring stations were established in 2000 (Fig. 1). MS1 and MS2 are located in areas where field surveys were conducted (Sullivan Creek and Deep Creek). MS2 is located in a 30 ha fenced area from which cattle have been excluded since the mid-1980s; browsing effects at this station are unequivocally due to wildlife. MS3 and MS4 are respectively located in the French and American Creek drainages.

Transect for repeat photography. Two kinds of photographs were taken: a) a panoramic series, and b) a photograph down a permanent transect line (Fig. 2). When taking the transect photo, the camera was positioned above the steel stake. The transect bearing was recorded on the sketch map. A metric tape was extended down the transect line. A metric stadia rod was included for scale; the location of the stadia rod was recorded on the sketch map.

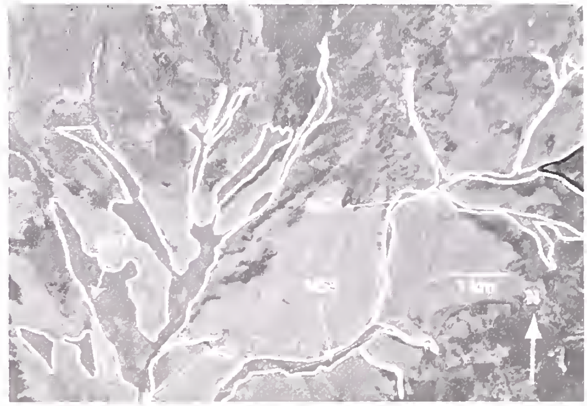


Fig. 1. *Location of monitoring stations.*

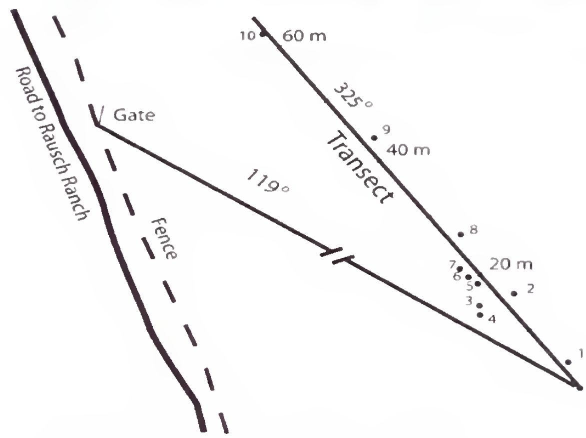


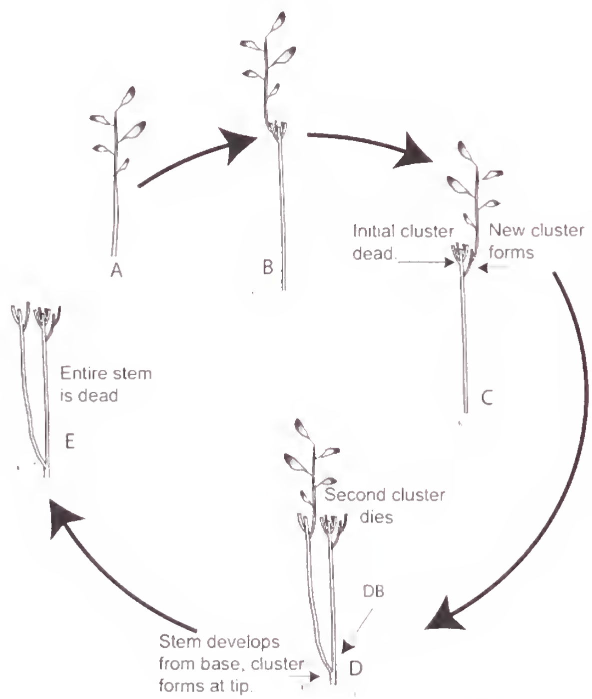
Fig. 2. *Sketch map of transect at monitoring station 1.*

Along the transect line, the location of 10 Geyer willow plants was documented by recording their distance along the transect line and their offset (N/S or E/W) from that line. Two heights were recorded for each plant: a) the height to the base of the tallest current-year-growth (H_{pyg}), and b) the height to the tip of the tallest stem killed by browsing (H_D).

A typical transect photograph is shown in Fig. 3. While photographs provide tangible evidence of plant condition, their interpretation is subjective. By documenting the location and measurement of 10 plants, we provide future viewers a limited quantitative perspective. The effect of browsing often is difficult to see in photographs that are taken late in the growing season when current-year-growth extends well beyond the twig clusters.

Fig. 3. *Photograph down transect at monitoring station 1.*

Trend assessment based on LD Index. This index expresses the difference between the height of live stems and the height of stems killed by browsing. The index was based on the following observations. Willow shrubs with dead stems are common throughout Mt. Haggin Wildlife Management Area. Such shrubs are typically composed of stems of different age as represented by the types shown in sequence A-E (Fig. 4). From establishment to death, a typical stem progresses through the following history. Stems are light-to-moderately browsed until they grow above snowcover or



above other forms of mechanical protection (A).

Once the stem is available to ungulates, browsing causes clusters of twigs to form at the tip (B in Fig 4). After a period of time, the cluster-bearing portion of the stem dies, and one or more lateral branches develop from a lower position on the stem; these branches assume the role of terminal leader. The lateral branches might develop at the base of the original cluster (C), or may develop at the base of the original stem (D). Clusters of twigs form on the new terminal leader, and after a period, the new terminal leaders die. Finally, the entire above-ground portion of the stem dies (E).

The LD Index monitoring method is based on the difference in the height of stems killed by browsing versus the height of live stems. Where there are both live and dead stems present, there are three possible relationships:

a) Live and dead stems may be at the same height,
b) Live stems may be below the height of the dead stems, and
c) Live stems may be taller than the dead stems.

The relationships would be produced as follows. The dead clusters of twigs form a zone of mechanical protection. The young stems that develop from the base of the shrub are typically not browsed until they extend beyond the dead stems. Once live stems extend above that mechanical protection, browsing begins and a new cluster of twigs develops. Under these circumstances, the base of current-year-growth is about the same height as the dead cluster of twigs (C and D).

As browsing pressure continues and the vigor of the shrub diminishes, the base of the current-year's-growth may fall below the level of the dead stems. Alternatively, if a plant is protected from browsing, the base of current-year's-growth will progressively grow above the height of the stems killed by browsing. These height relationships form the basis of one method of assessing trend during monitoring.

Stems from 20 plants were selected for measurement based on height and vigor. To meet the height criterion, the base of current-year-growth of the tallest stem had to be within the zone 75 - 200 cm above the ground. Stems in this region are exposed to browsing. Shorter plants were measured when necessary.

Of plants meeting the height criterion, the most vigorous were selected for measurement. The reasoning was as follows. For the full-statured community to persist, tall plants must be replaced as they die. The tall plants are relatively long-lived, so only a few young individuals must grow to full stature. For that reason, we biased sampling to include those plants that most likely would suc-

Table 1. LD Index. This index applies to plants in which some stems have been killed by browsing. Values greater than zero indicate that the live stems have grown taller than the stems killed by browsing. Values near zero indicate that the stem is browsed at about the same level as the dead stems (dead stems provide mechanical protection from browsing). Values less than zero indicate that the plant is dying back to ground level.

Monitoring station	LD Index ± SE inches (cm)	Maximum value inches (cm)	Minimum value inches (cm)
1	-4.8 ± 2.1	11.4	-26.8
	(-12.3 ± 5.4)	(29)	(-68)
2	-15.1 ± 3.9	0	-61.0
	(-38.3 ± 10.0)	(0)	(-15)
3	-3.3 ± 1.4	5.1	-19.3
	(-8.5 ± 3.5)	(13)	(-49)
4	0.7 ± 2.2	22.8	-12.2
	(1.7 ± 5.5)	(58)	(-31)

ceed. Plants were not marked for remeasurement in subsequent years; each year's sample is based on a new selection that might or might not include plants measured in previous years.

The height of the tallest stem was measured to the base of current-year-growth (H_{pyg}). Stems killed by browsing were identified by bite marks and clusters of twigs. Height was measured to the tip of the dead stem (H_D). The LD Index was calculated from: $H_{pyg} - H_D$. Values near zero indicate that browsing limits current-year-growth to the zone of mechanical protection. Negative values indicate that the community is in significant decline. Positive values indicate recovery.

LD Index data indicate that Geyer willow is in decline at all monitoring sites; most current-year-growth that extends above the limit of mechanical protection is consumed during the winter (Tab. 1).

At MS1, MS2, and MS3, the mean LD Index was less zero, while the mean LD Index of 1.7 at MS4 was very close to zero. Out of the entire sample set of 80 stems, only 16 had LD Index values greater than 0, 9 of which were at MS4. The maximum LD Index value encountered was 58 cm; this stem was at MS4. The low LD Index values confirm what can be seen with the eye during the growing season. From a distance, many willow stands are brownish in color; stems with leaves are obscured by taller dead stems.

Trend assessment based on $NAGR_{L3}$. The second of the two monitoring methods is based on the minimum growth rate that will enable a stem to grow out of ungulate reach before it dies. Dead stems, such as those seen in Fig. 3, Part 1 (P. 18), are evidence that browsing can kill. It follows that heavily browsed stems have a limited period to grow out of reach. We determined the lifespan of heavily browsed stems by taking sections of dead stems (presumed to have been killed by browsing) and counting the number of annual rings. Most sections were taken from the region labeled DB in the figure above (Type D). The average age at death was 10.2 ± 0.3 years (± SE, N=116, unpublished data).

We established a threshold $NAGR_{L3}$ value as follows. If a stem does not grow tall enough to escape browsing within about 10 years, dieback will occur. We used 2.5 m as the height of escape. To grow 2.5 m in 10 years, the stems must grow an average of 25 cm per year. Where other species are monitored at other locations, a corresponding stem lifespan and threshold growth rate would have to be determined.

The stems selected for LD Index measurement were also used for $NAGR_{L3}$ measurements. The following data were collected from each stem:

1. Lcyg (length of current-year-growth). In this example, assume that the data were collected in August 2000. The current-year-growth segment would have been produced the same growing season, that is, in 2000 (Fig. 5).
2. L1 (live length of the segment produced the previous year—i.e., in 1999.
3. L2 (live length of the segment produced the previous year—i.e., in 1998)
4. L3 (live length of the segment produced the previous year—i.e., in 1997)

The growing season years were determined by inspection of terminal bud scars. If a complete annual increment died, the length for that year

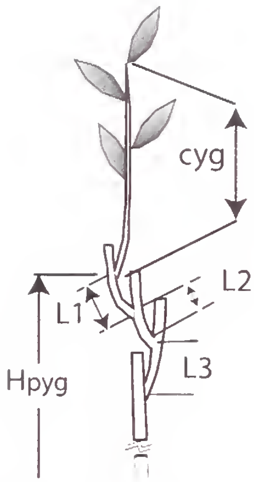


Fig. 5. *Segments measured for LD Index.*

would be entered as zero. For example, if the segment produced in 1998 died, the 1999 segment might develop from the 1997 segment. The remains of the 1998 segment would be identifiable from terminal bud scar relationships. Because the 1998 segment did not contribute to live stem length, its value—with respect to growth rate—is zero.

Because monitoring data will be collected each year, we need to be able to distinguish between data collected in different years. A two-part nomenclature is used. The first part refers to the segment type (Lcyg, L1, L2, or L3); the second part, written as a subscript, refers to the year in which the data were collected. For example, $L1_{2000}$ refers to an L1 segment that was measured in 2000.

Growth that occurred during a single year can be tracked over a subsequent three-year period. For example, $L1_{2001}$, $L2_{2002}$ and $L3_{2003}$ would all be expressions of the fate of current year growth produced in 2000.

The net annual growth rate for the preceding three years ($NAGR_{L3}$) was calculated by (L1 + L2 + L3) / 3. The resulting value was compared to the threshold value of 25 cm / year.

Mean $NAGR_{L3}$ values for all four sites were well below the threshold value of 25 cm / year (Tab. 2). Of the 80 stems sampled, only 7 exceeded the threshold value; 5 of these were at MS4.

The $NAGR_{L3}$ method of measuring growth rate is rapid and nondestructive. However, there are sources of error that should be considered. Under heavy browsing pressure, stems undergo cycles of growth and dieback. During periods of dieback, some stem segments will likely be within the protective zone of dead stems. Such stems will have larger $NAGR_{L3}$ values compared to stems where all segments were exposed to browsing. Factors unrelated to browsing may reduce growth rate. For example, current year growth values in drought years might be lower compared to values in moist years.

Browsing may inhibit height growth in three ways. First—and most obvious—consumption removes material that would otherwise have contributed to height. Second, browsing-induced stress may reduce growth potential. Third, browsing may inhibit height growth by running out the stem's biological clock. Young stems elongate rapidly when they are young, and slow down as they mature. Because intensely browsed stems undergo cycles of dieback, a 1-m-tall stem might be 10-20 years old at the base. On such stems, we have observed that current-year-growth is sometimes only a few cm in length. Such stems might have entered into an age-related phase of reduced growth.

Summary of trend.

The surveys and monitoring conducted at Mt. Haggin Wildlife Management Area in 2000 indicate

Table 2. Net Annual Growth Rate (NAGR) based on the average stem length added during the previous three growing seasons. At Mt. Haggin, browsed stems have an average lifespan of about 10 years. To grow out of ungulate reach before they die, stems must have a Net Annual Growth Rate of about 10 inches (25 cm) per year or greater.

Monitoring station	$NAGR_{L3} \pm SE$ inches / year (cm / year)	Maximum value inches / year (cm / year)	Minimum value inches / year (cm / year)
1	4.4 ± 1.0	20.4	0.5
	(11.2 ± 2.5)	(51.7)	(1.3)
2	3.3 ± 0.6	11.3	0.7
	(8.5 ± 1.5)	(28.7)	(1.7)
3	3.9 ± 0.6	9.4	1.1
	(9.9 ± 1.5)	(24.0)	(2.7)
4	5.6 ± 0.9	13.5	0.8
	(14.2 ± 2.4)	(34.3)	(2.0)

that Geyer willow is in decline. During the field surveys, no individuals exposed to browsing were found to have uninterrupted-growth- or released-type architectures. During monitoring, we sampled the most vigorous plants. LD Index data indicate that current-year-growth is browsed back to the level of mechanical protection. The preponderance of negative LD Index values indicates that major dieback has already occurred. The site-wide average $NAGR_{L3}$ values are well below the threshold value of 25 cm / year.

The quantity of available browse will diminish as dieback progresses. If the moose population remains approximately constant, increased pressure will be placed on the remaining browse plants. All lines of evidence indicate that, if present trends continue, the willow community will likely be converted to a meadow. To reduce browsing pressure, the moose harvest quota was increased by 50% for the 2000 hunting season. During the winter of 2000/2001, snowdepth was markedly less compared to typical years. The reduced snowpack allowed moose to disperse over a broader area compared to years in which snow is uniformly deeper. These factors are expected to influence willow growth. To document that response, we will conduct surveys and monitoring on an annual basis.

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Notes

A Method for Determining the Onset Year of Intense Browsing

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Abstract

A survey based on browsing related architectures indicated that browsing level had increased at the Mt. Haggin Wildlife Management Area. We describe a technique for determining the year in which the increase in browsing level occurred. The technique is based on the analysis of stems old enough to have experienced the early period of light browsing; the onset year of intense browsing was determined by using dendrochronology to date the formation of twig clusters produced by intense browsing. Stems from 20 Geyer willow (*Salix geyeriana* Anderss.) plants were analyzed from each of 6 study sites. Mean onset years at the 6 sites ranged from 1983.1 to 1988.4; the mean onset year for all 6 sites was 1985.4 ± 0.5 SE (N=120). The reconstructed history was used to evaluate the relationship between moose (*Alces alces*) number and browse trend. From 1976 to 2000, the winter trend census of moose increased from 7 to 56. The onset of intense browsing in 1985 occurred when 23 moose were counted.

Key Words: ***Alces alces*, architecture, browse-use history, moose, ungulate, willow**

A browsing history describes levels of browsing that existed over time. Such histories have many management applications. For example, a browsing history has contributed to philosophical discussion on "what is natural" in Yellowstone National Park (YNP) (Despain et al. 1986, Kay and Wagner 1994, Keigley and Wagner 1998). Where there is historic information on ungulate population size, a historic browse condition can be associated with the ungulate population size that was present at the time (Keigley 1997b, 1998); the reconstructed history may allow a manager to attribute a historic browse condition to one ungulate species rather than another.

Despite the potential management applications, the widespread use of browsing histories is uncommon. In part, the uncommon use may be due to the relatively youthful state of technique development. As we describe below, the application of different techniques has resulted in the inconsistent reconstruction of browsing histories. In part, uncommon use may arise out of lack of appreciation for the potential management applications.

There are 4 principal sources of information from which to reconstruct browse-use histories: 1) scientific reports that document browse use at different points in time, 2) comparison of photographs taken at different points in time, 3) age structure analysis, and 4) the analysis of browsing-related architectures. Browse-use histories typically draw on a combination of sources. For example, Houston (1982) reconstructed a browse-use history on the northern elk winter range of YNP based on scientific reports and comparison of historic photographs with more recent photographs. Kay (199) reconstructed a browse-use history of aspen *(Populus tremuloides* Michx.) based on scientific reports, photographs, and age structure analysis. Working in the same area as Houston and Kay, Romme et al. (1995) and Ripple et al. (2001) reconstructed a browsing history of aspen based on age structure. Keigley (1998) reconstructed a browse-use history of a cottonwood stand (*Populus angustifolia* James) on the YNP northern range based on the dendrochronologic analysis of browsing related architectures. An architecture-based browse-use history of a second YNP cottonwood stand was reconstructed using a combination of height and age data (Keigley 1997b).

Browsing-related scientific reports describe first-hand accounts of browse use. In the Yellowstone National Park (YNP) reports over the period 1935-1957 primarily include descriptions of the effects of browsing on growth form and mortality; beginning in 1958, areal distribution and plant height were measured (unpublished data, YNP). The use of reports for history reconstruction is limited to locations for which information was recorded. In an area such as YNP, much information is available, but in many areas, browse-related studies were not conducted historically.

A comparison of photographs taken at different points in time provides a visual perspective of browse use. As is the case of scientific reports, the use of photographs is limited to sites for which they are available. The interpretation of historic photographs is subjective, and as a result, interpretations may vary. For example, in an examination of early photographs taken in YNP, Houston (1982) found that conifers were highlined, indicating that intense browsing had occurred since the earliest EuroAmerican presence. In an examination of the same photographs, Kay and Wagner (1994) found that conifers were not highlined indicating that, prior to the establishment of YNP in 1872, browsing was light.

While reports and photographs provide a perspective on gross historic changes, neither source of information provides the resolution of data with which to reconstruct a year-by-year history of browse use. To accomplish this requires the ability to document the year-by-year state of a parameter over an extended period. One parameter in common use is the growth of an aspen stem to breast height. Based on the assumption that growth to breast height corresponds to a year of light browsing pressure, browsing histories are reconstructed by describing the age classes of stems that are present at a site (e.g., Kay 1990, Romme et al. 1995, Ripple et al. 2001).

In an age-structure-based history reconstruction, growth to breast height is a tangible form of evidence, while the evidence for intense browsing is intangible (i.e., intense browsing is inferred from the absence of an age class). The intangible nature of this evidence can lead to difficulty in 2 ways. First, evidence of growth may be missed. Based on the absence of older age-class aspen, Romme et al. (1995) concluded that aspen were insensely browsed prior to the 1870s. In a further examination of YNP aspen, Ripple et al. (2001) discovered evidence for these older age classes, leading to an interpretation that aspen was lightly browsed during that period. Even if evidence for the older age classes had not been found, the significance of that absence would be uncertain because factors unrelated to browsing may have been responsible for the lack of recruitment.

Architectural analysis is the process of reconstructing past browsing conditions based on the dendrochronologic dating of morphologic features; some features are produced by light browsing, others by intense browsing (Keigley 1997a, Keigley and Frisina 1998). The morphological features provide tangible evidence of both light and intense levels of browsing that occurred in the past (Keigley, 1997b, 1998).

We describe a method for reconstructing a history of browsing applicable to sites where browsing pressure has increased from a light-to-moderate level to an intense level. We describe how, during a preliminary reconnaissance, a manager can use gross architectural evidence to identify the condition that browsing intensity increased at some time in the past. We then describe methods for determining the year in which the increase occurred. The paper also describes an application of that reconstructed history.

Materials and Methods

Study Area

The study took place on a portion of the 22,743-ha Mt. Haggin Wildlife Management Area located in southwest Montana about 18 km south of the town of Anaconda (45°58´ N, 113°4´ W). The study area consists of a combination of wet and dry meadows. Willows (*Salix* spp.) are common along numerous stream courses and in wide riparian areas created by beaver dams. Elevation of the study area is about 1900 meters; annual precipitation is about 51 cm (Frisina 1992).

Prior to 1976, the area was privately owned (Newell and Ellis 1982). Domestic livestock grazed pastures continuously and intensively; willow was sprayed, dozer-piled, and burned to create more grassland for livestock. In 1976, the Montana Fish, Wildlife & Parks (MFWP) purchased the land and established Mt. Haggin Wildlife Management Area to provide habitat for wildlife and public recreational opportunities (Frisina 1982). The reduction of willow stopped. Populations of moose (*Alces alces* L.), elk (*Cervus elaphus* L.), mule deer (*Odocoileus hemionus* Merriam), and pronghorn antelope (*Antilocapra americana* Ord) increased (Frisina 1982, Kuntz 1993). Recently, whitetail deer (*Odocoileus virginianus* Merriam) began using the study area during the summer.

Moose are the only large ungulate present on the study area during winter; they concentrate in willow bottoms as snow accumulates. Deer, elk and antelope inhabit the area during snow-free months, when herbaceous plants are generally preferred and all habitat types are available for foraging. After establishment of the wildlife management area, livestock numbers were reduced (Frisina 1992). A rest-rotation grazing system was established in 1984, in which cattle are allowed access to a pasture during the growing season once every third year. Under the new grazing system, livestock were excluded from a 30-ha area; since that time, this area has only been used by wildlife.

Detecting an increase in browsing pressure

Keigley and Frisina (1998) distinguish between 2 browsing levels: a) light-to-moderate, and b) intense. Light-to-moderate browsing is defined to occur when curent-year-growth develops from the previous-year's-growth. Intense browsing is defined to occur when browsing causes the death of a complete annual segment. In this case, current-year-growth develops from a segment that is older than the previous-year's-growth.

At the whole-plant level, the effect of browsing is expressed in the form of 4 general types of architectures (Fig. 1). The architectures are produced during the period of time that the terminal leader is exposed to browsing. The 4 architecture types correspond with 4 browsing regimes:

1) Uninterrupted-growth-type architecture is pro-

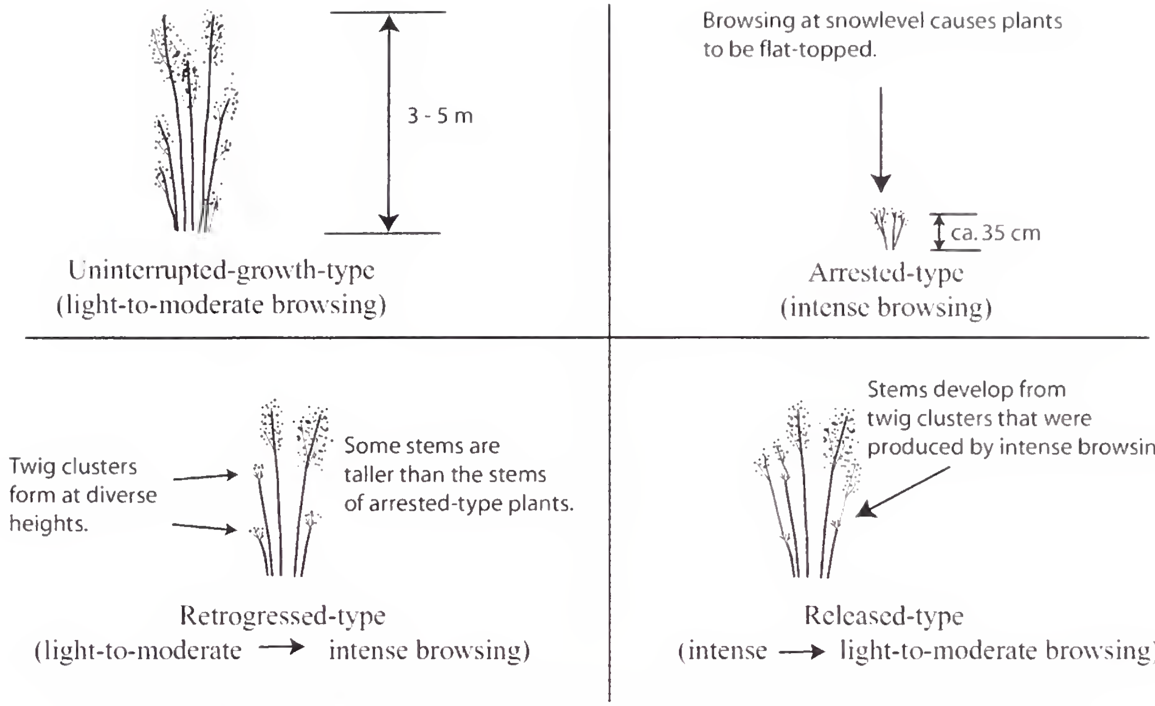

Fig. 1. *Four architecture types that are produced by 4 browsing regimes. The architectures are produced during the time that the terminal leader grows within the browse zone.*

duced by light-to-moderate browsing as the terminal leader grows through the browse zone.

2) Arrested-type architecture is produced by intense browsing since establishment.

3) Retrogressed-type architecture is produced by a change from light-to-moderate browsing to intense browsing.

4) Released-type architecture is produced by a change from intense browsing to light-to-moderate browsing.

In general, similar-aged plants of the same species and site should have experienced a similar level of browsing over their lifetime, and should have the same architecture. On sites where browsing pressure has changed, plants of different age may have different architectures; those architectures should express a similar history. For example, at a site where browsing pressure has increased from light-to-moderate to intense, one might find older retrogressed-type plants and younger arrested-type plants. Given the difference in plant ages, both architectures are consistent with an increase in browsing pressure. At Mt. Haggin, the relationship between willow age and architecture indicated such a history (Fig. 2). The objective of this study was to determine the year in which the increase occurred.

Geyer willow (*Salix geyeriana* Anderss.) is widely distributed and is substantially used by ungulates at Mt. Haggin. We stratified segments of Deep Creek, Sullivan Creek, and Dry Creek into 6 sample sites; the sites were distributed along a total distance of 3 km. Using the methods described below, we determined the onset year of intense browsing of Geyer willow for each of the six, 0.2-ha sample sites.

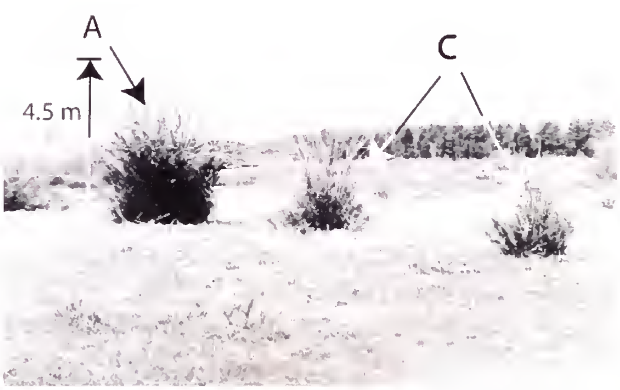

Fig. 2. *Older willow plants (A) have grown to heights of 4.5 m tall, while the youngest plants (B) are browsed to within 35 cm above ground level. The ability of the older plants to grow taller than 35 cm indicates that browsing was less intense in the past. At the time browsing level increased, many stems on plant A were out of ungulate reach. The stems of plants of intermediate age (C) were browsed at the height present at the time the increase in browsing pressure occurred. Plants A and C have retrogressed-type architecture; plant B has arrested-type architecture.*

Determining the onset year of intense browsing

Overview

The stem morphology produced by light-to-moderate browsing is distinctly different from the morphology produced by intense browsing. Stems that

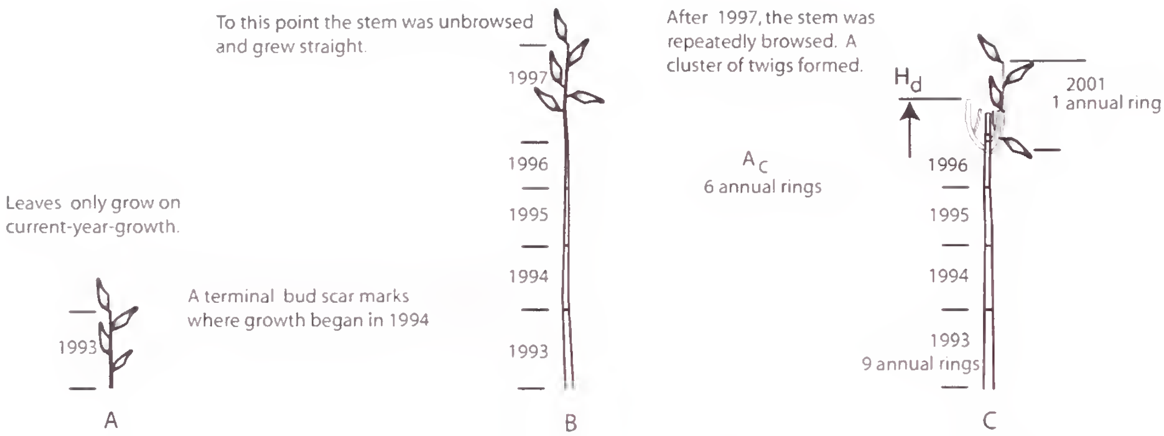

Fig. 3. *Stem with live twig cluster. The year of browsing can be directly determined. Stems A, B, and C show how plant would appear in during the growsing seasons of 1993, 1997, and 2000, respectively.*

have experienced an increase in browsing level would have the light-to-moderate browsing morphology at the base (where the stem first elongated) and intense-browsing morphology at the distal end. Using dendrochronology, we determined the year in which those morphologic changes occurred.

The stem morphologies are produced as follows. The annual sgments of a light-to-moderately browsed stem develop from stem segments produced during the previous year. The new segment may develop either from the previous-year's terminal bud or, if that bud aborted, from lateral buds slightly lower down the stem. Ungulates typically consume segments produced the most recent growing season (current-year-growth). The browsing removes the terminal bud insuring that, if subsequent growth occurs, it must arise by activation of a lateral bud. The stem dies between the point where it was bitten and the point where new growth emerges the following growing season. If ungulates repeatedly consume a minor portion of each year's current-year-growth, the stem grows in a zigzag manner, with dead stubs located at intervals on the stem.

Under heavy browsing pressure, ungulates consume major portions of current-year-growth, leaving behind a stub of the current annual segment. Because the dead stub is tough and unpalatable, it mechanically protects stems that may subsequently grow beneath it. If ungulates repeatedly browse current-year-growth to a point even with the dead stubs from preceding years, a compact cluster of twigs develops (Fig. 3). Browsed twigs are abruptly terminated by bite marks that are easily distinguishable from other sources of disturbance such as disease or insect infestation. A compact cluster of twigs with bite marks is morphologic evidence of intense browsing. We used dendrochronology to determine the year in which twig clusters formed.

Determining the year of twig cluster formation

The dendrochronologic dating of morphologic features involves determining the year in which a given stem segment was a terminal leader. For a stem segment collected from the beginning of a growing season through the end of the calendar year, the formula for determining the year of initial elongation is:

$$Y_{E=} \text{ collection year} - A + 1. \quad \textbf{(1)}$$

where Y_E is the year that the stem elongated and A is the number of annual rings in the stem segment. For example, a current-year-growth segment collected in August 2001 would have a single annual ring. The year of elongation is:

$$Y_E = 2001 - 1 + 1 = 2001 \quad \textbf{(2)}.$$

The +1 corrects for the annual ring produced during the current calendar year. If the segment had 9 annual rings, Y_E would equal 1993. To determine the year of elongation when the stem segment is collected the next calendar year, but before the growing season (e.g., in February), the +1 correction would not be made. The stem segment must be live at the time of collection.

Stem C in Fig. 3 records 2 periods: a period of light-to-moderate browsing (in which the lower stem grew straight) and a period of intense browsing (in which the cluster of twigs formed). Using the formula above, the number of annual rings just below the twig cluster (A_C) can be used to determine the last year in which the terminal leader grew under light-to-moderate browsing (Y_C = Collection year – A_C + 1). Because the stem at point AC is live (and by our definition, light-to-moderately browsed), we assume that intense browsing began the following year ($Y_1 = Y_C + 1$). To use this

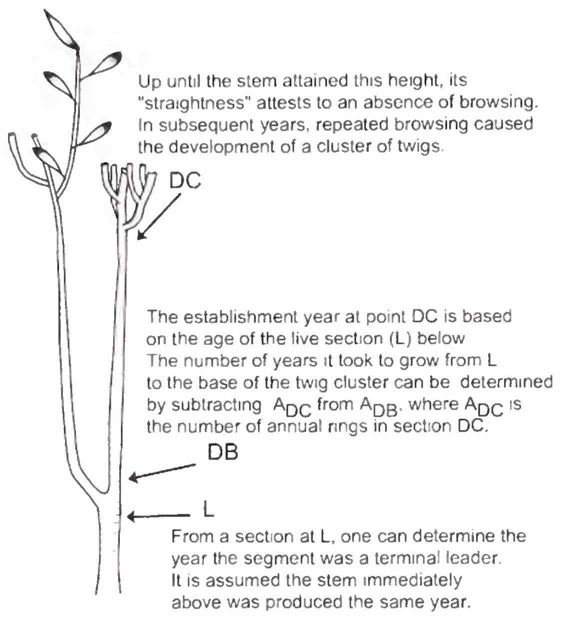

Fig. 4. *Stem in which dieback has occurred; the initial twig cluster is dead. To determine the initial year of browsing, the dead twig cluster must be linked to a live stem segment.*

method of dating, the twig cluster must be live; we refer to it below as the "live twig cluster method."

Protracted browsing often causes stem dieback of the original stem, with the development of new terminal leaders from the base of the stem (Fig. 4). Because the base of the twig cluster is dead, the annual rings there cannot be directly associated with a given year. To make that association, one must link the dead twig cluster to a live segment of the stem. The onset year of intense browsing is determined from 3 sections:

1. Section L from the primary stem just below the point where the live secondary stem originates. The year that this stem segment was a terminal leader is determined from the number of annual rings. Ring development in section L may be asymmetrical depending on how close the section is to the dead primary stem above it; when counting annual rings, care must be taken to include those produced during the most recent growing season.
2. Section DB from the dead primary stem immediately above the point where the live secondary stem originates. An assumption is made that the stem at point DB was a terminal leader the same year as at point L. When making collections, the length between points L and DB was typically 2-5 cm, so it is likely that the sections were produced the same growing season.
3. Section DC from the base of the dead twig cluster. The difference in the number of annual rings in sections DB and DC indicates the number of years it took for the stem to grow to the base of the cluster. It is assumed that cluster formation began the following year.

The year of twig cluster formation is calculated as follows:

$$Y_I = [\text{Collection year} - A_L + 1] + [A_{DB} - A_{DC}] + 1 \quad \textbf{(3)}$$

The first bracketed term indicates the year that the linking section was a terminal leader; A_L is the number of annual rings in the linking segment. As above, +1 may or may not be added depending on when the collection was made. The second term, $[A_{DB} - A_{DC}]$, indicates the number of years it took the stem to grow to the base of the cluster. The first 2 terms added together indicate the year that the stem at the base of the cluster was a terminal leader. As above, the second +1 is added because browsing intensity is assumed to have increased the year after the stem grew to point DC. Below we refer to this method of dating as the "linked segment method."

Collection and examination of section

Sections were collected with hand shears and examined under a dissecting microscope. Sections of live segments were not sanded; sanding of soft (moist) wood tended to collapse the vessel walls, obscuring the view. In cases where the annual rings were not clear, a thin slice was removed with a razor blade. Sections of dry, dead segments were sanded; the view was clarified with a razor as necessary.

Selection of stems for dating

We determined the onset year of intense browsing from 20 Geyer willow stems at each of the 6 study sites. Each stem was collected from a different shrub.

At sites where browsing level increases from light-to-moderate to intense, all shrubs will eventually have either arrested=- or retrogressed-type architecture. Plants with arrested-type architecture may be established after the increase occurred. The dating of twig cluster formation on such plants would indicate a time subsequent to that establishment, not when the initial area-wide increase in browsing occurred. The year of the area-wide increase is only recorded in stems old enough to have experienced both the early period of light-to-moderate browsing and the subsequent period of intense browsing. Such stems are found on retrogressed-type plants.

With respect to suitability for dating, retrogressed-type shrubs can be placed in 2 categories. In one category are retrogressed-type plants that, at the time browsing level increased, had stems that were tall enough to escape ungulate browsing (ca 2.5); these tall stems would not develop morphologic evidence of the increased browsing. After

browsing increased, such shrubs would continue to produce stems, some of which would be mechanically protected from browsing within the interior of the shrub. Stems that were within ungulate reach at the time browsing increased would develop twig clusters indicative of the onset year. However, stems that have been mechanically protected within the interior of the shrub may elongate beyond mechanical protection and develop twig clusters. These clusters would not indicate the onset year. Because there is no sure way to distinguish between those possibilities, we avoided this category of retrogressed-type plant.

The second category of retrogressed-type plants consist of those whose tallest terminal leaders were within the browse zone at the time browsing increased. When possible, we selected retrogressed-type plants that were 75-200 cm tall; height was measured at the tip of dead twigs in the cluster (H_d in Fig. 3). The 200 cm height is well within the reach of moose. We were concerned that plants less than 75 cm tall might be too young to have experienced the area-wide increase in browsing. Stems within the 75-200 cm height range were fully exposed to browsing, and were likely old enough to have been present when the area-wide increase occurred. When enough plants within this height range could not be located within the sample area, stems from plants somewhat shorter than 75 cm were included in the sample.

We sampled the oldest live stem from the selected plant. We assessed stem age in 2 ways. First, we selected stems having large basal girth in comparison to other stems in the shrub. Second, when possible, we selected stems having dead twig clusters. Because protracted browsing kills the upper stem, stems with dead twig clusters are most likely to record the earliest browsing events. The effect of including stems shorter than 75 cm tall and stems with live twig clusters was analyzed by comparing the results of the full data set with results obtained when plants not meeting the above criteria were removed.

Results and Discussion

Dating the onset year of intense browsing

In a preliminary survey we found that all Geyer willow exposed to browsing had either arrested- or retrogressed-type architecture. The lack of uninterrupted-growth-type individuals indicated that the current browsing level was intense. Older Geyer willows had retrogressed-type architecture, while younger plants had arrested-type architecture (see Fig. 2). This relationship between age and architecture indicates that browsing level has increased. Using the methods described above, we determined that the onset year of intense browsing averaged across sites was 1985.4±0.5 SE (N=120)(Table 1).

Effect of including live twig clusters and plants less than 70 cm tall

For the following reason, we were concerned that the use of live twig clusters might skew the result to a more-recent date. The formation of twig clusters indicates when a stem was first exposed to intense browsing. In the case of the oldest stems, twig cluster formation indicates an area-wide increase in browsing pressure. In the case of younger stems, such as those with live twig clusters, cluster formation may indicate when the stem grew taller than some form of mechanical protection. Out of the total sample of 120, 4 dates were obtained from stems with live twig clusters. We examined the effect of including live-twig-cluster data by excluding those data and recalculating a pooled mean. The resulting date was identical: 1985.4±0.5(±SE).

The average age of the stem at the base of the dead twig clusters was 10.2 ± 0.3 years (± SE) (Table 1). This age suggests that live twig clusters may reliably indicate the onset of intense browsing for periods up to about 10 years. To document an onset of browsing that occurred more than 10 years in the past, one should sample stems with dead twig clusters and determine the onset date by the linked seg-

Tab. 1. Location of sample sites, year intense browsing began, and lifespan of heavily browsed twigs. N = 20.

Site	Year intense browsing began Mean ± SE N = 20		Age (years) at base of dead stem Mean ± SE N = 20	
1	1986.9	± 0.7	10.6	± 0.5
2	1988.4	± 0.9	8.2	± 0.7
3	1983.1	± 1.5	10.2	± 0.8
4	1983.7	± 0.9	11.4	± 0.5
5	1986.9	± 1.1	10.1	± 0.7
6	1983.6	± 1.3	11.5	± 0.7

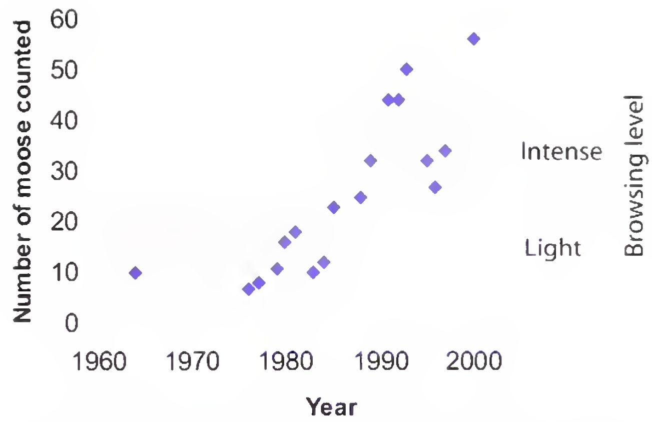

Fig. 5. *Relationship between moose census number and browsing intensity. Based on the pooled data, browsing intensity changed from a light-to-moderate level to an intense level in 1985. The horizontal line indicates the range of onset dates that occurred over the 6 study sites.*

ment method.

We were concerned about the potential effect of including plants less than 75 cm tall. Because the age of the plants was not known at the time of sampling, we were concerned that short plants might be too young to accurately reflect the earliest increase in browsing pressure. We examined the effect of sampling 11 such plants by excluding them from the data set. The resulting mean onset year was 1985.4 ± 0.5 SE, a value identical to those above.

Comparison with other methods of history reconstruction

Architectural analysis and age structure analysis can be used to document past levels of browsing at any site where shrubs of suitable age are present; scientific reports and photographs can only be used where this information was recorded in the past. Age structure analysis can only document periods of light browsing in which stems grew; because the absence of an age class can be caused by multiple factors, periods of intense browsing and transitions in browsing levels cannot be dated. Architectural analysis dates the transition from a morphology produced by lightly browsing to a morphology produced by intense browsing; as a result, periods of intense browsing are documented and a history is reconstructed that has fewer gaps.

The technique described above provides a repeatable method of determining a date at a given sites. Because ungulates prefer some browse species over others, the date applies only to the browse species on which it was based. By measuring the onset dates of other species, one can examine interspecific patterns of browse use.

An application of the reconstructed history

The study area lies within Montana Fish, Wildlife & Parks (MFWP) moose Hunting District 325. Moose population data collected during winter aerial surveys of Hunting District 325 from 1964 through 2000 were used to determine population trend (Fig. 5). In any census, the data represent the actual number of moose observed; the total number of moose in the population is greater (Anderson and Lindzey 1996). We view the census data as an index of trend.

Three lines of evidence indicate that moose are primarily responsible for the recent impacts on browse plants. First, heavy browsing occurs at a site where livestock have been excluded since 1984 (Site 1). Browsing within this 30-ha area must have been due to wild ungulates. Second, the average onset years for intense browsing (1983-1988) coincide with the period in which the HD 325 moose population was increasing most dramatically. During this period, a grazing system was established that lessened the impact of livestock (Frisina 1992). Third, because of mid-winter snow conditions, moose are the only ungulate to occupy the area year-round. These factors suggest that moose played an important role at all 6 sites.

The lack of willow with uninterrupted-growth type architecture suggests that the willow carr is in the process of conversion to a meadow-like condition. The fact that this conversion began during a period of a moose population increase suggests that, to reverse the trend, the population must be reduced.

The reconstructed history indicates the magnitude of the required reduction. The increase in browsing pressure first occurred in 1983 (at Site 3) when 10 moose were counted. The latest year to mark the increase in browsing was 1988 (at Site 2)

when 25 moose were counted. In the mean onset year of 1985, 23 moose were counted. We conclude that, to reverse the trend to a meadow-like condition, the moose population must be reduced by about half. In 2000, the moose harvest quota was increased by 50%. A monitoring program has been instituted to determine the effect of moose reductions.

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Habitat Changes

Mount Haggin Wildlife Management Area, Montana.

Michael R. Frisina and Richard B. Keigley

In 1984, after more than 60 years of continuous season-long livestock grazing, a rest-rotation grazing system was established on the Mount Haggin Wildlife Management Area (MHWMA) in southwest Montana (3,4). Prior to implementing the grazing system, a number of photo-monitoring points were established on the MHWMA at locations where cattle concentrate while grazing. A photo essay shows changes observed at photo points in riparian, lowland, and upland sites within the grazing system. Additionally, gross changes in the amount of willow present are documented using aerial photo interpretation.

Mount Haggin Wildlife Management Area

The 55,000-acre MHWMA is located approximately 10 miles southeast of Anaconda, Montana, and is administered by the Montana Department of Fish, Wildlife and Parks (MFWP). The area is a mixture of wet and dry meadow types, grass/shrublands, and forest. Willows are common along numerous stream courses and wide riparian areas enhanced by beaver dams. During the 1960's willows were directly reduced by spraying, dozing, and hay mowing. Willows were also indirectly reduced due to intensive beaver trapping reducing the number of dams. Willow and beaver were considered hindrances to range forage and hay production for use in raising sheep and cattle. Lodgepole pine is the most common forest cover type; Engelmann spruce is also present in small populations near riparian areas. A significant portion of the lodgepole pine and spruce on the drier, less precipitous sites has been clearcut and is regenerating. The elevation of MHWMA lands within the rest-rotation grazing system varies from 5,500 ft. to 8,000 ft.; annual precipitation is about 20 inches.

Substantial populations of Rocky Mountain elk and moose inhabit MHWMA. Mule deer and black bear are also common. Small populations of pronghorn antelope and whitetail deer are present during spring, summer, and early fall. Beaver and sandhill cranes are the most common nongame species of general interest. Beaver populations have increased over the past 20 years as a result of conservative harvest quotas. Response of elk to the rest-rotation grazing system was described by Frisina (4) and sandhill cranes by Frisina and Canfield (5). The effect of an expanding moose population on the willow community was addressed by Keigley et al. (10), Keigley et al. (11), and Keigley et al. (12). The response of small mammal populations to the different grazing treatments provided by the grazing system was described by Douglass and Frisina (1).

Rest-Rotation Grazing System

The Mount Haggin grazing system consists of a three pasture rest-rotation system incorporating approximately 20,000 acres using a design based on principles described by Hormay (6) and Egan (2) (Figure 1). August L. Hormay consulted with

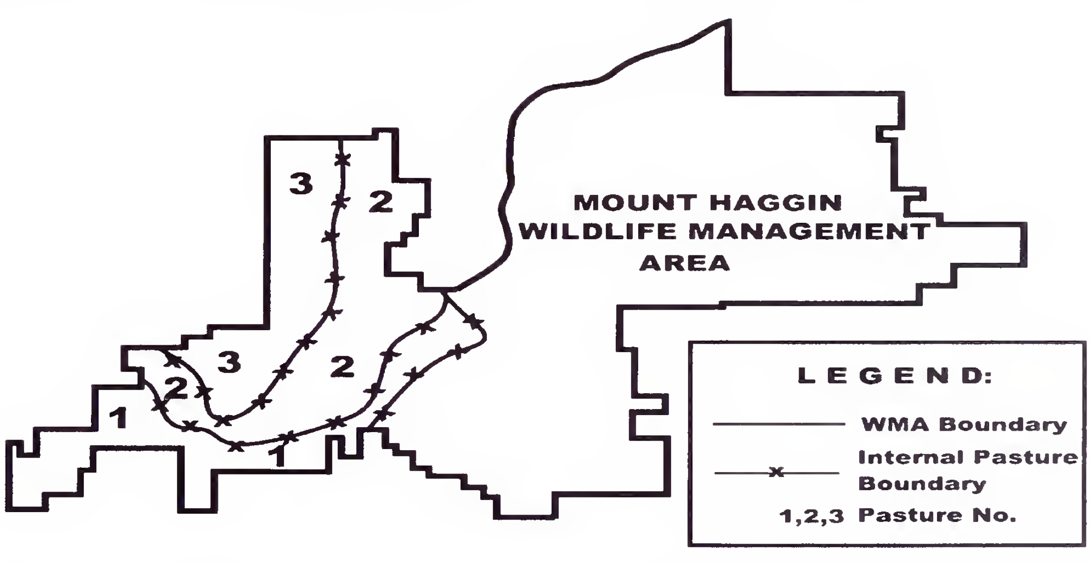

Fig. 1. *The Mount Haggin Wildlife Management Area rest-rotation grazing system consists of three pastures.*

MFWP to design the grazing system. The three pastures vary in size from about 6,000 acres to 8,000 acres. They are approximately equal in livestock grazing capacity and are fenced off from each other. Fencing allows for cattle control, but does not significantly inhibit movements of free ranging elk and other large wild ungulates.

The annual grazing season begins in mid-June and ends on October 15. The allowed grazing level is set at 4,000 Animal Unit Months (AUMs) annually. In a particular year, the livestock operator may graze fewer cattle than allowed, but may not exceed the 4,000 AUMs. Numbers of elk, moose, and deer within the grazing system are controlled by regulated hunting (7,8) Each of the three pastures receives one of the following three grazing treatments annually (Figure 2):

A Treatment – Pasture is available for cattle grazing throughout the entire grazing season but is primarily grazed during the growing season. This pasture is also available to free-ranging wildlife. When seeds are ripe on pasture vegetation (seedripe), cows and calves are moved to the pasture scheduled for the B treatment; in some years bulls are left behind in the A treatment pasture until they are removed from the area.

B Treatment – Cows and calves are moved to the B treatment pasture near the end of the growing season, at seedripe time. Cattle remain in the B treatment pasture until the end of the grazing season.

C Treatment – Rested from livestock grazing for the entire year and available for free-ranging wildlife use only.

Each pasture receives one treatment annually. In effect, cattle graze two-thirds of the system during a single grazing season, but only one-third is grazed during a single growing season. Following grazing of a pasture by cattle during the growing season (A treatment), that pasture is rested from livestock grazing for the next two growing seasons (by following the A treatment with the B and C treatments, respectively) (Figure 2).

The rationale for this approach is as follows: The B and C treatments provide vegetative rest, which maintains maximum plant vigor and food storage, and enables plant seedlings to become established by allowing a full year for them to develop a root system prior to potentially being grazed by cattle. Since the system allows for plants to fully complete their aboveground biological life cycle 2 out of every 3 years without being grazed, the system encourages plant diversity and growth of new vegetation in bare soil areas (6,2). B treatment pastures are not grazed until seeds are developed on the slowest maturing plants (mid-August). The slowest maturing important plant at the MHWMA was determined to be bluebunch wheatgrass. Using this

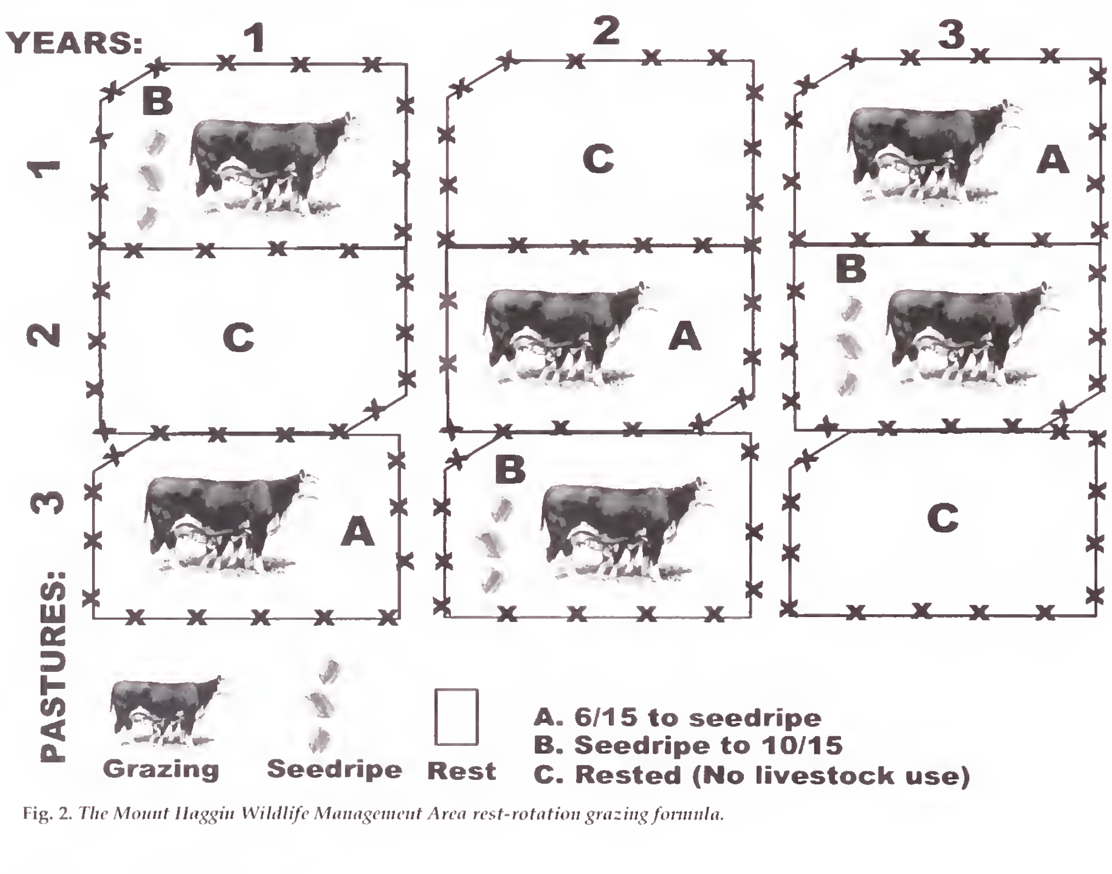

Fig. 2. *The Mount Haggin Wildlife Management Area rest-rotation grazing formula.*

species as an indicator, we can generally assure that most plants will be at or past the seedripe stage of development prior to applying the B treatment.

At seedripe (mid August), cattle are allowed access to the pasture scheduled for the B treatment by being moved from the pasture that received the A treatment. Hoof action by cattle in the B treatment pasture helps trample or fix seeds into the soil. This trampling creates microenvironments (depressions) conducive to moisture retention and protection of seedlings through germination (6,2). The C treatment (rest from cattle grazing) always follows the B treatment. As previously mentioned, this allows seedlings time to grow and establish root systems prior to being subjected to cattle grazing.

In principle, the approach enables plants to maintain maximum vigor and food storage, which enables rapid post-grazing recovery during the long rest periods (6, 2). The rest-rotation system is designed to allow for the maintenance of healthy, diverse, and vigorous rangeland vegetation. The aforementioned is an update to the details of the MHWMA rest-rotation grazing system described by Frisina (4).

Plant Community Changes

Sites preferred by cattle including historic salting areas or resting areas, where use by livestock is intense, were the preferred sites for photo monitoring. The rationale we used was that if positive changes became apparent at these intensely used locations, then it could be assumed that less intensely used areas were also improving. This approach was used because the grazing program is not a research project, but an ongoing management action and monitoring is included with other duties of the wildlife manager at MHWMA.

A number of management changes have been implemented on the MHWMA since its establishment in 1976, so changes in vegetation cannot be solely attributed to any one action. However, the single most significant land use action by MFWP was changing from more than 60 years of continuous season-long livestock grazing to a rest-rotation grazing strategy. Vegetation in uplands, riparian, and meadow habitats is responding favorably in the face of livestock grazing that has occurred under the rest-rotation grazing system since 1984 (Figures 3 through 9).

Additionally, habitats capable of supporting willow may still be recovering from the 1960's when willow was removed over large areas by spraying, bulldozing, and hay mowing (Figure 8 and 9). These destructive practices ended by the early 1970's, prior to MFWP ownership. Currently, destruction of willow is still a common practice on some private lands in the upper Bighole River Watershed. Another impact on willow and other browse species has been increased use by big game populations inhabiting the MHWMA since its acquisition in 1976. Management actions by MFWP have encouraged deer, elk, and moose to increase (3). This is particularly true of winter use by moose which has resulted in an increase in browsing intensity (12). This increase in browsing not only produces hedge-like clusters of twigs (9), but the browsing of young willows may also promote the development of root suckers. Over the past three decades, browsing pressure by moose has increased (12). In addition to the aforementioned management changes, the increased browsing by moose may be partly responsible for the increased distribution and density of willow outside the riparian corridor. However, concern that moose browsing has increased to a point that willow is being reduced in quantity on the MHWMA has prompted MFWP to intensify efforts to monitor willow communities and increase the moose harvest by hunters to control the population.

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Fig. 3. *The upper photo was taken by A. L. Hormay in 1977 when the area was under season-long continuous livestock grazing. The lower photo was taken in 1990 near the end of the A treatment (grazed mid-June to mid-August) under the rest-rotation grazing system. Cattle grazing remained continuous until 1984 when the rest-rotation grazing system was implemented. The lower photo was taken during the seventh grazing season under rest-rotation grazing management. The left white arrow in the upper photo serves as a reference point for the lower photo in Fig. 4. Note that some areas of exposed soil or visible animal trails appear vegetated in 1990.*

Fig. 4. *Close up photos of the same 2 cabins shown in Fig. 3. Both photos were taken in 1991 prior to cows being placed in the pasture. The upper photo indicates the area that was mostly exposed soil in 1977 (Fig. 3) has vegetated with a variety of meadow grasses and forbs. The foreground in the lower photo is within the area obviously intensively used by cattle in both of the Fig. 3 photos (refer to the left white arrow in the upper photo in Fig. 3).*

Fig. 5. *The upper photo of an historic livestock salt ground was taken by A. L. Hormay in 1979 when the area had been subject to continuous and season-long grazing for more than 55 years. Continuous grazing was practiced another four years until 1984 when the rest-rotation grazing system was implemebnted. The lower photo was taken in 1990 during the seventh grazing season under rest-rotation management.*

Fig. 6. *The upper photo of an historic salt ground was taken by A. L. Hormay in 1978 when the area was still subject to continuous grazing. Continuous grazing continued for another five years until 1984 when the rest-rotation grazing system was implemented. The lower photo was taken in 1990 during the seventh grazing season under rest-rotation grazing management.*

Fig. 7. *The upper photo of cottonwood was taken by A. L. Hormay in 1984, the year rest-rotation grazing was implemented on the Mount Haggin Wildlife Management Area. The photo was repeated in 1990 during the seventh year of the rest-rotation grazing system. Note the growth in height and width of cottonwood even though not protected from livestock grazing by fencing.*

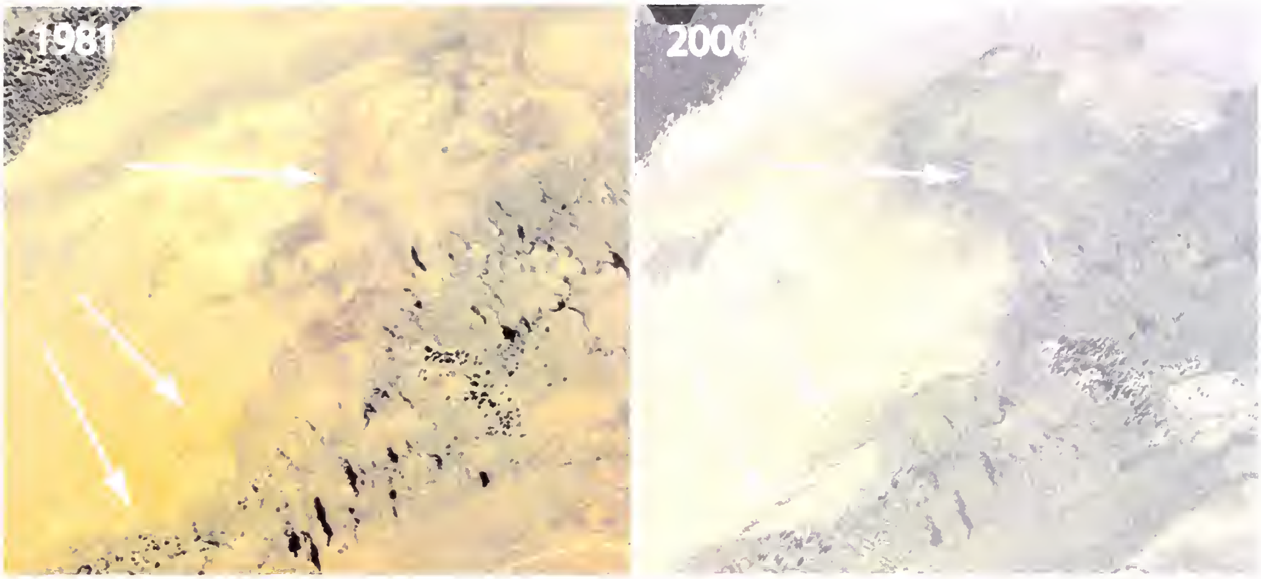

Fig. 8. *Aerial photographs document changes in willow distribution. Arrows in the 2000 photograph (right) indicate areas in which willow has expanded compared to the same areas shown in the 1981 photograph (left). Several factors appear to have influenced the increase in willow distribution that has occurred over the past two decades, including stream migration, an increase in the beaver population, browsing by moose, and the cessation of season-long livestock grazing.*

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Fig. 9. *The upper photo was taken by dick Oswald (MDFWP) in 1980 when the area was still subject to continuous season-long grazing. Continuous grazing continued another three years until 1984 when the rest-rotation grazing system was implemented. The lower photo was taken in 1991 during the eighth grazing season under rest-rotation management. Note vegetation on gravel bar.*

A Method to Determine if Browsing Limits Plant Height Growth

Richard B. Keigley

Abstract

The purpose of this study was to determine if browsing played the dominant role in limiting the height growth of chokecherry at three stands in eastern Montana. At each site, stems were measured and sectioned to determine the rate of stem growth that occurred before the first browsing event ($NAGR_{BB}$) and rate of growth that occurred afterward ($NAGR_{AB}$). Stem morphology was used to identify the occurrence of browsing. Mean $NAGR_{BB}$ was 20±2 cm/year (±SE, N=59); mean $NAGR_{AB}$ was 3±0.2 cy/y (±SE, N=59). Analyses of growth rate versus year showed no pattern that could be associated with climate. The greater variation of $NAGR_{BB}$ was attributed to differences in site condition, plant vigor, and a sample-selection artifact. The reduced variation in $NAGR_{AB}$ values suggests that browsing results in a reduced growth rate that is maintained at a low, relatively constant level. A graphical method was used to distinguish between browsing and age-related influences. A comparison of $NAGR_{BB}$ with the growth rate of stems growing inside an ungulate-proof exclosure (33.9 ± 3.5 cm/y [±SE, N=25]) showed that $NAGR_{BB}$ underestimates actual growth potential. The underestimation occurred because stem consumption and stem dieback caused the remaining length of live, unbrowsed stem to be less than the length of stem that actually grew. Underestimation can be reduced by restricting the sample to stems with unbrowsed lengths greater than 30 cm long. The method described in this study can be applied in areas where big game exclosures have not been constructed.

Introduction

Many factors affect the height to which a plant can grow, including climate, site conditions, age, and browsing. Ungulate browsing often received special attention because browsing pressure is a variable that can be regulated by management action. Studies on the effect of browsing range from attributing reduced height growth completely to high browsing pressure (Chadde and Kay 1991, Keigley 1997, Ripple and Beschta 2003), to attributing reduced height rowth to the combined effect of browsing and environmental conditions (Singer, et al. 1994, Despain et al. 1986). The fact that all of the above studies were conducted in the same area indicates that distinguishing between factors can be problematic. This study describes a method of determining if browsing was the principal factor that influenced height growth.

Chokecherry (*Prunus virginiana*) was the subject of the study. Chokecherry is distributed across much of the United States and southern Canada (Johnson 2000). The species reproduces both vegetatively and from seed, and can assume either a shrub or tree growth form (Harrington 1964, Schier 1983, Parciak 2002). Vegetative reproduction from rhizomes can produce extensive thickets or small clusters of stems, depending on the spacing and number of ramets that are produced. Chokecherry is grazed by livestock although the leaves produce toxins that can be harmful (USDA 1937). The species is ecologically important as wildlife food and habitat (Stubbendieck et al. 1992). In Montana, chokecherry is moderately used as forage by mule deer during all seasons of the year (Kufeld et al. 1973); it is highly valuable to elk (Kufeld 1973).

This study was conducted in eastern Montana approximately 26 miles south of Terry, MT (47°5.34N 105°37.36W). At the study area chokecherry grows along the sides and bottoms of woody draws (Fig. 1). Stems range in height to about 2.5 m tall. Ungulates present at the site include mule deer (*Odocoileus hemionus*), white-tailed deer (*O. virginianus*), and livestock. There were three study objectives:

Fig. 1. *Chokecherry grows along the bottom, side, and periphery of woody draws in eastern Montana. Growing conditions and plant vigor vary depending on location within the woody draw. Because many stems are established from rhizomes, vigor of the parent plant can also affect the vigor of young stems.*

1. Determine the percent of stems that were intensely browsed.
2. Determine if browsing was the principal factor that limited height browth, and if so,
3. Determine the extent to which browsing reduced height growth.

Methods

Measurements and samples were taken in 2003 from three chokecherry stands exposed to browsing and from a stand inside a big game exclosure

that excluded ungulates. The 2.5-m-tall, 0.5-ha big game exclosure was constructed in the late summer of 2000. The three outside areas were respectively located approximately 10, 200, and 400 m from the exclosure.

Twenty stems 50- to 100-cm tall were examined to determine the percent of stems that were intensely browsed at each site outside the big game exclosure. Plants were defined to be intensely browsed when they met the following criteria: 1) a complete annual segment was dead, and 2) that segment showed evidence of having been browsed (Keigley and Frisina 1998). Sampled stems were selected by identifying 20 sample points within the respective stands that were approximately equally spaced-from one another.

Additional measurements and samples were taken from 10 stems in the height class 0- to 50-cm tall and 10 in the height class 51- to 100-cm tall: 1) height to the base of current-year-growth (HB_{CYG}), 2) the length of the live dowel-like segment of stem

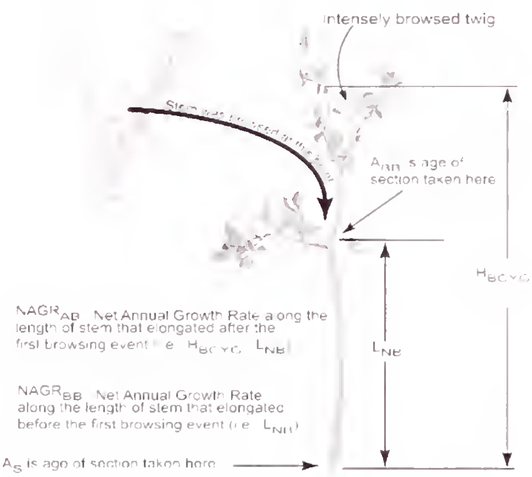

Fig. 2. *Location of measurements and samples taken from intensely browsed stems. The lack of branching along the segment L_{NB} indicates that browsing did occur during the elongation of this segment. Arrows at the top of the stem point to leafless, dead, browsed twigs that were the basis for classifying this stem as intensely browsed. The first browsing event occurred midway up the stem.*

growing at the base of the plant (L_{NB}), 3) a section from the base of the L_{NB} segment, and 4) a section taken from the top of the L_{NB} segment (Fig. 2). The age of stem sections was determined by a count of annual rings, A_S being the age of the lower section and A_{NB} the age of the upper section. As above, stems were sampled along a line transect with the two closest stems meeting the above criteria measured and sampled at each of 10 points along the line.

The dowel-like segment elongated prior to the first browsing event. The growth rate for that section was designated $NAGR_{BB}$ ("net annual growth rate before browsing") and was calculated as $L_{NB}/(A_S - A_{NB} + 1)$. The value $(A_S - A_{NB} + 1)$ is the number of growing seasons over which segment L_{BB} elongated. The growth rate for browsed period of the stem's life was designated $NAGR_{AB}$ ("net annual growth rate after browsing") and was calculated as $(H_{BCYG} - L_{NB}) / (A_{NB} - 1)$. One year was subtracted from A_{NB} to eliminate the growth ring produced the current year.

Four collections totaling 25 unbrowsed stems were sampled from inside the big game exclosure: 1) 10 stems spaced equidistant along a line transect, 2) 5 stems from the interior of clusters of stems that were >2 m tall, 3) 5 stems growing in close proximity to those tall clusters of stems, and 4) 5 stems that were not associated with tall clusters of stems. The following measurements and samples were taken: 1) height to the base of current-year-growth (H_{BCYG}), and 2) a section from the base of the stem. Data from the four collections were pooled. The net annual growth rate of those stems was designated $NAGR_T$ and calculated as $NAGR_T = H_{BCYG} / (A_S - 1)$. One year was subtracted from the total age of the stem to eliminate the annual ring produced during the current growth year.

Results and Discussion

All stems 50- to 150-cm tall were intensely browsed. Browsing level at each of the three sites exposed to browsing was classified as 100% intensely browsed.

A 90-cm tall 19-year-old stem was excluded from the growth rate analyses; the stem had died back to ground level and subsequently resprouted at ground level resulting in an L_{NB} of zero. The respective mean $NAGR_{BB}$ values at the three sites were 22.0 ± 2.9, 17.8 ± 2.9, and 19.5 ± 2.7 cm/y (±SE; N = 20, 19, and 20). A test by ANOVA indicated no significant difference between sites (P=0.585). The grand mean $NAGR_{BB}$ of browsed plants from all sites was 19.8 ± 2 cm/y (± cm SE, N = 59). The average number of growing seasons over which the L_{NB} segments grew was two years (i.e., after an average of two years, the stems were browsed).

The mean $NAGR_T$ of unbrowsed plants inside the big game exclosure was 33.8 ± 3.5 cm / y (±SE, N = 25). $NAGR_T$ is the mean potential growth rate at the site under recent climate conditions. $NAGR_{BB}$ was significantly less than $NAGR_T$ (P<0.001).

Based on the growth rate of unbrowsed plants in the big game exclosure ($NAGR_T$), $NAGR_{BB}$ was a significant underestimate of the potential growth rate at the study area. A known issue contributed to that underestimation, namely: the length of stem

used to calculate growth rate (L_{NB}) was shorter than the length of stem that actually grew. When the stem was browsed the first time, a part of the initial stem was consumed and thus not included in the measurement. A second source of error was caused by stem dieback, a common response to browsing. When dieback occurs, new growth develops at a lower point on the original stem. Because the growth rates must be based on ages from live stem sections, the dead region above the new growth was not included in the measurement of L_{NB}. In this study, some L_{NB} measurements were as short as 2 cm. The effects of the under-measurement of L_{NB} are: 1) to underestimate $NAGR_{BB}$, and 2) to overestimate $NAGR_{AB}$. When the analysis was restricted to stems with L_{NB} lengths of at least 30 cm, mean $NAGR_{BB}$ was 29.9 cm/y (compared to an $NAGR_T$ of 33.8 cm/y). The accuracy of $NAGR_{BB}$ could be improved by restricting sample selection to stems with a minimum L_{NB}; however, such selection could raise questions about sample bias. The full dataset was used in the following analyses.

The respective mean $NAGR_{AB}$ at the three sites were 3.2 ± 0.4, 3.6 ± 0.4, and 2.5 ± 0.3 cm/y (±SE; N = 20, 19, and 20). A test by ANOVA indicated no significant difference between sites (P=0.114). The grand mean $NAGR_{AB}$ of browsed plants from all sites was 3.1 cm per year (± 0.2 cm SE, N = 59). The variances of $NAGR_{BB}$ and $NAGR_{AB}$ were 158.3 and 2.0, respectively; analysis by the Levene test for homogeneity of variance showed that the variances significantly differed (P<0.001). $NAGR_{AB}$ was significantly less than $NAGR_{BB}$ at all sites (Mann-Whitney U test, P<0.001).

The reduction in growth rate at the top of the stem ($NAGR_{AB}$ compared to $NAGR_{BB}$) could be due to browsing, recent climate conditions, or -because growth rate diminishes with stem age—an age-related reduction in growth rate. The potential influence of those factors was assessed based on the following premises: 1) a dominant climate influence would produce a time series pattern in growth rate that corresponded to some aspect of the climate record, 2) a dominant browsing influence would cause an abrupt reduction in growth rate that would be little influenced by stem vigor, and 3) a dominant age-related influence would cause a gradual reduction in growth rate that would be significantly influenced by stem vigor.

Graphs of $NAGR_{BB}$ versus year and $NAGR_{AB}$ versus year suggest no pattern that could be related to climate (Fig. 3). Recent variation in climate was rejected as the principal explanation for the differences between $NAGR_{BB}$ and $NAGR_{AB}$.

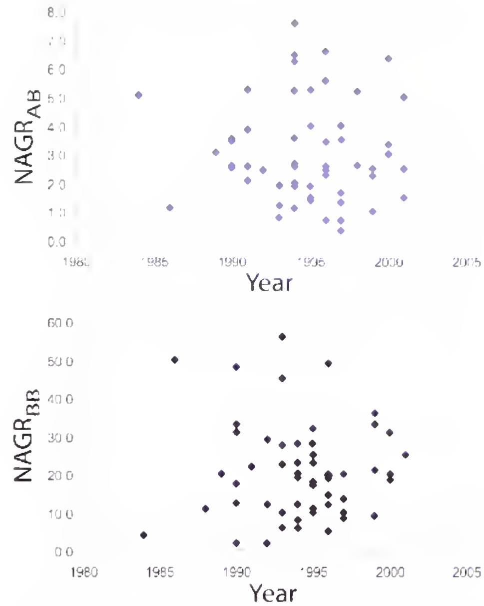

Fig. 3. The upper graph is $NAGR_{AB}$ versus year that the stem grew above L_{NB}; the lower graph is $NAGR_{BB}$ versus establishment year. There was no consistent pattern that could be compared to climate variables.

The variation between $NAGR_{BB}$ and $NAGR_{AB}$ was examined by plotting those values versus the height of the stem from which those measurements were taken (Fig. 4). The range in $NAGR_{BB}$ values is

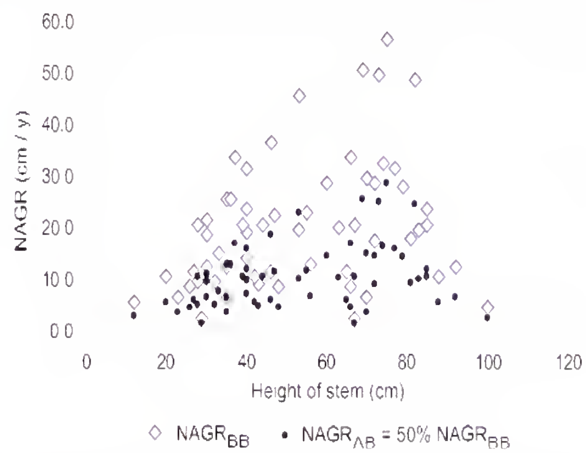

Fig. 4. Graph of $NAGR_{BB}$ and $NAGR_{AB}$ versus the height of the stem on which the measurements were taken; each value of $NAGR_{BB}$ corresponds to a value of $NAGR_{AB}$. The vertical distance between corresponding values indicates the change in growth rate that occurred after the browsing event. Multiple factors contributed to wide variation in $NAGR_{BB}$. After the first browsing event, $NAGR_{AB}$ wa maintained at a relatively constant low value. This abrupt change in growth rate was inferred to indicate a significant role of browsing.

due in part to differences in LNB that were measured (as described above), and due in part to variation in climate, site condition and vigor of individual stems. In contrast, $NAGR_{AB}$ varies relatively little; regardless of age, once stems are exposed to browsing, the rate of height growth is constrained

to a low value.

To illustrate how an age-related reduction in growth rate would appear if graphed similarly, a hypothetical dataset was constructed based on stem height, $NAGR_{BB}$, and an assumed reduction of

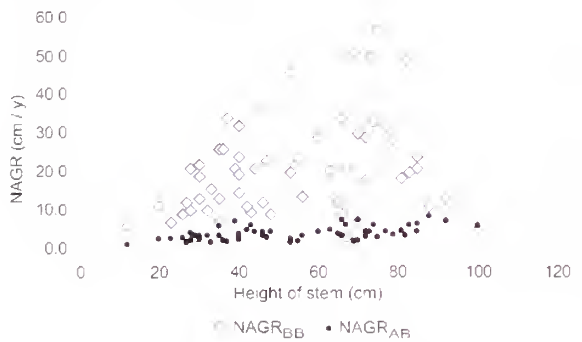

Fig. 5. *A hypothetical dataset illustrating the anticipated effect of a reduction in growth rate caused by age-related influences. $NAGR_{BB}$ was plotted as in Fig. 4. $NAGR_{AB}$ was assumed to be reduced by a percentage of the initial growth rate. In this case, factors that led to variation in growth rate during the early life of the stem ($NAGR_{BB}$) would continue to act during the latter life of the stem ($NAGR_{AB}$).*

50% of the initial growth rate (Fig. 5). In this case, the data points of the hypothetical $NAGR_{AB}$ values are scattered in a similar pattern to that of $NAGR_{BB}$ but are reduced in value. The abrupt reduction in growth rate to a relatively constant value indicates that browsing played the significant role in limiting height growth during the latter part of the stem's life.

Having determined that browsing significantly limited height growth, the ratio between $NAGR_{AB}$ and $NAGR_{BB}$ provides a means of quantifying the browsing factor. At the study area, browsing induced a reduction in growth rate to approximately 16% of its initial rate (3.1 cm/y/19.8 cm/y). The browsing-induced reduction in growth rate would be influenced by consumption (removal of part of the stem), browsing-related physiologic stress on the stem, and a decrease in growth rate associated with increased stem age.

This study documented that: 1) 100% of the stems 50- to 100-cm tall were intensely browsed, 2) browsing was a significant factor that limited height growth, and 3) that browsing reduced growth to about 16% of the potential growth rate. The method described above can be used to document the effect of browsing in situations where big game exclosures have not been constructed. A big game exclosure provides an opportunity to document actual growth rates and determine the extent to which measurements from browsed plants lead to an underestimation of true growth potential.

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Cherry Creek Browse Study

Richard B. Keigley

The objectives of this study were to assess browse trend in the Cherry Creek area and reconstruct the history of browse use. The study was initiated by the Gallatin NF out of concern for apparent heavy browse use. Two willow stands were examined for trend, one in the upper drainage of Cherry Creek (12 457291E / 5036898N), the other along the main stem of Cherry Creek (12 457246E 5035975N). The reconstructed browse-use history was based on an aspen stand located at 12 459875E 50373778N; a history reconstruction of willow use was conducted at the upper Cherry Creek drainage site. Data were collected over a two-day period, July 16-17, 2001.

Assessment of browse trend

Upper drainage of Cherry Creek.

The site was visited July 16 and 17, 2001. Five species of willow were identified: Bebb willow (*Salix bebbiana*), Geyer willow (*Salix geyeriana*), Booth willow (*Salix boothii*), Wolf willow (*Salix wolfii*), and plane leaf willow (*Salix planifolia*). Of these species, Bebb, Geyer, and Booth willow commonly grow to 3-m-tall or more. At this site, most Bebb, Geyer, and Booth willows grew no taller than 1 meter; along the north edge of the stand, were a few plants that had grown to 4-m-tall.

The survey focused primarily on Geyer Willow. Browse trend was assessed based on: 1) architecture, 2) NAGR, 3) LD-Index, and 4) a graph of age versus height (Keigley and Frisina 1998).

Architecture. All individuals in the height range 50 - 150 cm had arrested- or retrogressed-type architectures. Based on this architectural survey, the site is 100% intensely browsed. The arrested- and retrogressed-type architectures indicate that, in the recent past, browsing has prevented young plants from attaining full stature.

NAGR. Two types of NAGR were measured: $NAGR_T$ and $NAGR_{L3}$. NAGR values are interpreted in the following way. Browsing reduces stem lifespan; the dead stems in this stand demonstrate that many have died before growing taller than 1 meter. The lifespan of heavily browsed stems can be determined by counting the number of annual rings found in those dead stems. If one assumes that a stem grows out of ungulate reach at about 2.5 meters, a benchmark growth rate can be calculated by dividing that height by stem lifespan. The measured NAGR values are then compared to that benchmark value.

Sections of 20 dead stems were collected. Based on a count of annual rings, the mean lifespan was 12.6 ± 0.5 years. To attain a height of 250 cm (i.e., to grow out of ungulate reach) within 12.6 years, a stem must grow at an average minimum rate of **20 cm / year**. This benchmark value was compared to the measured NAGR values described below.

$NAGR_T$ is the net annual growth rate calculated by dividing the height of the plant (measured to the base of current-year-growth: H_{pyg}) by the number of growing seasons it took the plant to attain that height (A_S - 1, where A_s is the number of annual rings counted in a section taken from the base of the stem). Stems from twenty plants were sampled. **$NAGR_T$ = 6.8 cm ± 0.8.** This value is substantially less than the benchmark value, indicating that, at this growth rate, these stems are unlikely to grow out of ungulate reach before they die.

$NAGR_{L3}$ is the net annual growth rate that a stem experienced during the previous three growing seasons. In this study, $NAGR_{L3}$ was determined by measuring the length of segments produced during the 2000, 1999, and 1998 growing seasons, adding those values, and dividing the sum by three. The same 20 stems were measured as above.

$NAGR_{L3}$ = 4.7 cm ± 0.9. As above, this value is substantially less than the benchmark value, indicating that, at this growth rate, these stems are unlikely to grow out of ungulate reach before they die.

LD-Index. In stands that have been heavily browsed, the LD-Index is a measure of the position of the height of live stems with respect to the height of stems killed by browsing. LD Index was measured on 20 plants 50-150 cm tall—these are plants attempting to grow through the browse zone. On such a plant, the tallest stem was selected (as measured to the base of current-year-growth, i.e., H_{pyg});

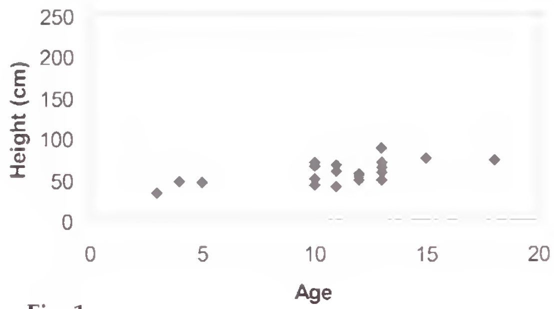

Fig. 1

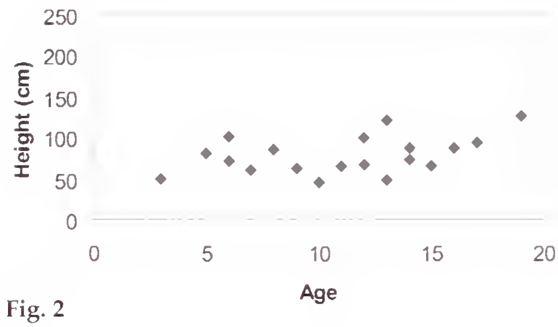

Fig. 2

the height to the tallest, dead heavily browsed stem was also measured.

LD Index = H_{pyg} - H_D, where H_{pyg} is the height to the base of current year growth, and H_D is the height to the tallest dead stem. Values around zero indicate that plants are being browsed down to the level of mechanical protection (mechanical protection is provided by the thatch of dead stems); values much less than zero indicate that plants are dying back to ground level; values greater than zero indicate that the plant is growing taller.

LD Index at this stand was **-13.0 ± 2.8**. The negative value indicates that willow is dying back to ground level.

Age versus stem-height relationships. In the absence of browsing, it is typical for plants to gain stature as they age. As can be seen in Fig. 1, plants at this site did not attain a meter in height, regardless of age.

Summary of trends. All four measures of trend (architecture, NAGR, LD Index, and age-height relationship) indicate that browsing has prevented young plants from attaining full stature.

Assessment of browse trend

Main stem of Cherry Creek.

The site was visited July 16, 2001. Trend data similar to those taken at previous site were collected. Geyer willow plants were examined.

Architectures. All willow plants within the browse zone had arrested-or retrogressed-type architecture. These architectures indicate that browsing has prevented young plants from attaining full stature.

NAGR. Based on a sample of 20 stems, heavily browsed stems lived an average 8.7 ± 0.4 years. Using a 2.5-m escape height, stems would need to grow an average of 29 cm /year if they are to grow out of reach before dying. $NAGR_T$ = 9.5 ± 1.3. $NAGR_{L3}$ = 11.4 ± 1.5. Both of these values are substantially less than the 29 cm / year benchmark value.

LD Index. LD Index = -3.0 ± 4.6. This value, which is close to zero, indicates that plants are being browsed to the limit of mechanical protection.

Age versus stem-height relationships. As in the previous site, these plants reached a browsing-related height plateau (Fig. 2).

Summary of willow trend. All methods of trend assessment indicate that browsing prevents young plants from attaining full stature.

Reconstruction of browse-use history

Aspen

The reconstructed history was based on architectural analysis. Three types of architectures were found: arrested-type, retrogressed-type, and uninterrupted-growth-type.

The oldest individuals (as shown in Fig. 3) had uninterrupted-growth-type architecture. The trunks of these trees were mostly straight; I saw no invaginations indicative of injuries that would have occurred when the trees were young.


Fig. 3

Fig. 4

In contrast to the straight trunks of older individuals, the trunks of the youngest uninterrupted-growth type individuals grew in a zigzag form (Fig. 4). A zigzag trunk would result if the terminal leader was browsed and subsequent growth developed from a lateral (as opposed to terminal) bud. Portions of the bark of these trees had been removed by rubbing and antler thrashing. The difference in scarring, between the oldest and youngest uninterrupted-growth-type individuals indicates an increase in ungulate use.

Individuals with retrogressed-type architecture (such as the one shown in Fig. 5) indicate a change from light-to-moderate browsing to intense browsing. The straight, lower stem grew during the initial period of light-to-moderate browsing. The forking and clustering of the upper stem took place after browsing changed to intense. The upper portion of this stem has been killed.

The individual in Fig. 6 has arrested-type architecture; this plant, which is about 20 cm tall, experienced intense browsing since the earliest part of its life.

The following sequence is indicative of an increase in browsing level: the oldest plants have uninterrupted-growth-type architecture, middle-aged plants have retrogressed-type architecture, and the youngest plants have arrested-type architecture.

Dendrochronology was used to reconstruct a more-precise browsing history. Years of light-to-moderate browsing were identified based on the establishment year of uninterrupted-growth type trees. The establishment year of 15 individuals was determined from counts of annual rings; cores were taken 30 cm above ground level. The sample of 15 was roughly divided into five individuals with the largest girth, 5 medium sized individuals, and 5 of the smallest. In addition, the smallest uninterrupted-growth-type individual was cut and sectioned. The establishment year was calculated by:

Fig. 5

Fig. 6

$Y_E = 2001 - A_S + 1.$

Two of the oldest retrogressed-type plants were cut; sections were taken from both the base (for establishment year) and from just beneath the point where forking and clustering began (A_C). Years of intense browsing for these plants was calculated by: $Y_I = 2001 - A_C + 2$. The earliest onset of intense browsing occurred in 1986.

The reconstructed history is presented in Fig. 7. The isolate points of light-to-moderate browsing indicate establishment years of uninterrupted-growth-type individuals. The absence of deep invaginations is evidence that the older stems were not injured in their youth. For that reason, I believe that light-to-moderate browsing occurred from the early 1900s to the mid-1980s.

Reconstruction of browse-use history

Willow at the Upper Cherry Creek site

As described in the trend assessment section, there is evidence that browsing is preventing young willows from attaining full stature. The ability of some plants to grow to 4-meter-tall, indicates that browsing was less intense at some time in the past. The architectural evidence indicates that there has been an increase in browsing pressure.

To estimate the year in which browsing increased,

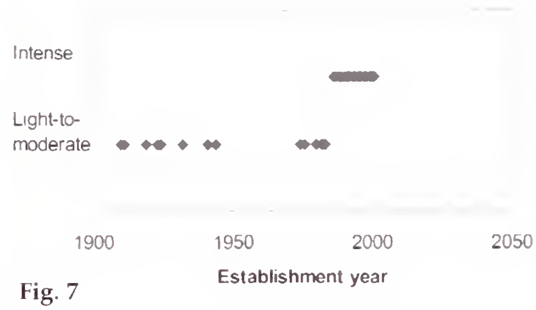

Fig. 7

7 stems believed to show early evidence of browsing were collected. All of these stems had live clusters of twigs; none had developed secondary stems from the base of the original stem. The development of morphologic features produced by browsing was dated using dendrochronology. On average, the morphologic features developed 1992 ± 0.8

A Possible Historical Scenario at the Upper Cherry Creek Site

The following scenario is based on willow age structure and distribution of willow stands, and ungulate population trends. This tentative scenario is presented primarily as starting point for future study.

In the foreground of Fig. 8, are tall, relatively old willows. Willows of this stature are absent from t

Fig. 8

he central wetland corridor. Young conifers grow in the central corridor; older conifers are absent.

In the downstream region of the central corridor are willows of "middle age" (Fig. 9). These plants are a meter or less in height. As can be seen in Fig. 8, these plants contain stems that have been killed, presumably, by browsing.

In the upstream region of the central corridor are relatively young plants, such as one shown in Fig. 10. Few or no dead stems are present.

Stand composed exclusively of young plants are evidence that the distribution of Geyer willow has

Fig. 9

Fig. 10

expanded in recent years (Fig. 11).

Hypothetical scenario: Late in the last century full-statured willows occupied the riparian corridor. Beaver were likely present. Grazing of the Cherry Cre ek allotment began in 1912 when 1000 to 1500 head of livestock used the area from April 15 to November 15. Tall willows may have been eliminated from much of the area after livestock grazing began. Because livestock grazing would have

Fig. 11

occurred during snowfree months, willows could be cropped close to the ground. The few remaining tall willows may be relics of plants that were established prior to establishment of the grazing allotment. If beaver were initially present, a decline in willow might have encouraged them to leave the area. If dams were abandoned, the site may have become drier, thus allowing the expansion of conifers into the riparian corridor.

Around 1930, the Spanish Creek and Cherry Creek allotments were split. From the1930s to 1989, livestock use continued, though at a lower level compared to the use that occurred early in the century.

In the mid-1980s, the browsing of aspen increased from light-to-moderate to intense. This increase in browsing pressure occurred during a period when wildlife populations were increasing.

In 1989, the Cherry Creek Allotment permittee took nonuse. Since 1989, livestock were absent (except for trespass) with following exceptions: 1990 (225 head from July 10 - October 5), and 2000 (220 head for two weeks). In general, there has been a substantial decline in livestock use since 1991.

The reduction in livestock use may have allowed the regrowth of willow in the downstream area (where willows up to 1-m-tall now grow) and the expansion of willows in the upstream direction (where very young willows are currently being established). As the young willows resumed growth, they would have been browsed by wildlife. The 1992 onset of intense willow browsing may reflect browsing by wildife that occurred once the young willows grew taller than the protection of snowcover.

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Aspen Height, Stem-girth and Survivorship in an Area of High Ungulate Use

Richard B. Keigley
Michael R. Frisina

Abstract

An increase in an ungulate population potentially exposes aspen suckers, saplings, and trees to an increased level of use. This study examined how stem height and girth influenced the selection of stems by ungulates for browsing, rubbing, and gnawing. Stems (leaders) in the approximate height range of 20 to 250 cm were browsed. Stems 2-13 cm diameter and greater than 80 cm tall were preferentially selected for rubbing and gnawing. The area of exposed xylem on dead saplings was 2-3 times the area of exposed xylem on live stems. In 2002 there were no live stems in the 76-349 cm height range; there were numerous dead stems in that range, all bearing evidence of rubbing, gnawing or browsing. Based on an analysis of stem height and age, ungulate use of the aspen clones was inferred to have increased from a light-to-moderate level to an intense level in 1991. We concluded that elk were primarily responsible. The findings of this study have implications for aspen restoration programs and wildlife management. Where ungulate numbers are high and aspen is desired, aspen should be protected from browsing, rubbing and gnawing until stems reach about 13 cm; in this study area, aspen would require about 25 years to grow to that size.

Introduction

Over the past several decades, aspen (*Populus tremuloides*) has declined in many areas of the Western United States (Kay 1997, White et al. 1998, Bartos 2001). Several factors have been implicated including disease, climate change, fire suppression, and impacts by wild and domestic ungulates (DeByle et al. 1987, Miguelle and Ballenbergh 1989, Despain 1990, Romme et al. 1995) This study explored how ungulates may affect aspen regeneration by browsing, gnawing on bark, and rubbing, either with the body or with antlers.

Multiple factors influence the regeneration of aspen stands. Growth regulators produced by mature stems can inhibit the development and growth of young suckers (Schier et al. 1985). Where conditions are conducive for the growth of young stems, ungulate influences can be significant. Intense browsing can prevent stems from growing to full stature (Keigley 1997, Keigley and Frisina 1998). Aspen has a persistent periderm, producing a thin, tender bark that can be removed by gnawing and rubbing (Figure 1). When the bark is partially removed, a rough, fungal infection (most commonly by *Macrophoma tumefaciens*) can lead to the development of a rough layered bark (Kaufert 1937). Injury to the stem can lead to infection by a variety of potentially lethal pathogens such as the sooty bark canker (*Cenangium singulare*) (Hinds 1985).

Fig. 1. *Aspen has a thin, tender bark that can be easily removed or injured. The elongate scars were likely caused by bull elk as they removed velvet from antlers. Gnawing by elk likely caused the smaller elliptically-shaped scars. The small stem in the foreground was a diameter of about 8 cm.*

In areas where ungulate numbers are low and where consistent aspen regeneration is occurring, stems will be present that range from short suckers to medium-size saplings to full-size trees. If ungulate numbers increase, those stems of diverse size are available for browsing, rubbing, and gnawing. This study was conducted in such an area. The objectives of the study were to: a) determine the influence of height and diameter on rubbing and gnawing, b) determine the influence of height and stem diameter on formation of rough bark, c) determine the effect of rubbing and gnawing on survivorship, and d) reconstruct the history of browsing at the study site.

Methods

Study area

The study was conducted on the 1,600 ha Mount Fleecer Wildlife Management Area (FWMA) that is administered by Montana Fish, Wildlife & Parks. The FWMA is located in southwest Montana near the town of Divide and ranges in elevation from about 1,500 – 2,000 m. Precipitation varies from about 36 to 46 cm annually. The FWMA was purchased in 1962 to provide winter range for elk (*Cervus elaphus*) and habitat for other wildlife. Over the past 50 years the Mount Fleecer elk population has increased from a census low of 160 in 1961 to a high of 1,718 in 1996. The FWMA is within the area described by Frisina and Morin (1991) as the

Fleecer Coordinated Grazing Program (FCGP); during the 1980's livestock use on the FCGP increased to the current level of about 714 cattle or 1,342 Animal Unit Months of grazing annually. Mule deer (*Odocoileus hemionus* ssp. *hemionus*) and white-tailed deer (*Odocoileus virginianus*) and a small population of pronghorn antelope (*Antolocapra americana*) also inhabit the FWMA.

Bluebunch wheatgrass (*Pseudoroegneria spicata*) and Idaho fescue (*Festuca idahoensis*) grasslands are the predominant vegetation with some lodgepole pine (*Pinus contorta*) and Douglas-fir (*Pseudotsuga menziesii*) occurring along higher elevations and southerly aspects. Big sagebrush (*Artemisia tridentata*) is interspersed throughout the grassland communities, especially on the southern portion of the area. Some rough fescue (*Festuca altaica*) is also present. Willow (*Salix* spp.) and aspen are common along stream banks and in wet areas. Three aspen stands were examined in this study; samples and data were collected in the summer of 2002. The stands were located on the east-facing flank of Mt. Fleecer, where they occur at the interface between lodgepole pine / douglas fir and sagebrush / grassland communities.

Measurements

The influence of stem size on the rubbing and gnawing of saplings(i.e., $\geq$ 2 m tall) was based on measurements taken along line transects. The respective influences on shorter individuals was based on measurements taken within 1-m wide belt transects.

Sapling stems were partitioned into four categories based on circumference at 1 m above ground level: 1) live stems < 40 cm circumference, 2) live stems 40-80 cm circumference, 3) live stems > 80 cm circumference, and 4) dead stems of any circumference. Stems were selected for measurement at 10-pace intervals along line transects running lengthwise within each of the three stands (A, B, and C). At the determined point, the closest stems were selected for measurement that met the above criteria. With the following exceptions, 20 individuals were sampled from each size class: a) stand A > 80 cm size class where N=5, b) stand C 40 – 80-cm size class where N = 16, and c) stand C > 80 cm size class where N = 15. In all cases, all individuals meeting the selection criteria were sampled. The following measurements were taken from each stem: a) circumference at 1-m above the ground, b) the length and width of each area of exposed xylem occurring from ground level to 2-m, c) depth of the deepest scar from bark to xylem, and d) the percent area of rough bark. Long, broad scars that were oriented slightly off vertical were assumed to have been caused by porcupine and were not included in the sample. Scars caused by antler rubbing were not distinguished from exposed xylem produced by gnawing.

Each area of exposed xylem was calculated as length times width; the area of individual scars on each stem was summed to calculate the total area of bare xylem on the stem. The total stem surface area within the 2-m length of stem was calculated as: 200 cm times circumference. For each stem, the percent area of exposed xylem of each stem was calculated by dividing the total bare area by the total stem surface area. Because stem girth had increased since scarring occurred, the measured circumference (converted to diameter) did not reflect the stem diameter at the time of scarring. Diameter at the time of scarring was estimated by subtracting the depth of the deepest scar (times 2) from the measured diameter. The influence of stem size (height and girth) on the rubbing and gnawing of older stems was determined by inspection of a graph of pooled data. The area of rough bark was classified into 1 of 6 cover classes: a) 0 - 5%, b) 6-25%, c) 26-50%, d) 51-75%, e) 76-95%, and f) 96 - 100%. The maximum height of rubbing and rough bark was measured on 20 trees from each stand.

A 1-m-wide belt transect was established in each of the three stands; the transect ran through the narrowest part of the respective stands. The following measurements were taken from each stem in the transects: a) height measured to the base of current-year-growth, b) age where possible to determine from examination of bud scars, d) diameter where stems were less than 8 cm diameter and where age could not be determined from bud scars, c) circumference at 30 cm for stems greater than about 8 cm diameter, d) presence or absence of scars produced by rubbing, and e) status: live or dead. Stem diameter was measured with a micrometer. The influence of stem size (height and girth) on the rubbing and gnawing of the younger stems was determined by identifying the shortest height and smallest diameter at which scarring occurred.

Where the age of stems could not be determined from bud scars, age was estimated using circumference on age correlation models constructed for each stand. Because the girth of young stems increases more rapidly compared to older stems, separate age *on* circumference models were constructed using: a) sections collected from stems < 23 cm circumference, and b) cores from stems > 23 cm circumference. Ten sections spanning a range of diameters were collected from each stand; diameter was converted to circumference. Cores from stems of a range of circumferences were collected: (17, 12, and 10 cores from stands A, B, and C respectively);

collection was at 30-cm above the ground. The ages of the sections and cores were determined by count of annual rings using a dissecting microscope.

The core-based and section-based correlation models for each stand were run to determine the point at which the models intersected (i.e., to determine the circumference that yielded the same age for both models). The circumference at the respective intersection points was used to determine which correlation model was used to estimate age, with the age of stems of smaller girth being estimated with the section-based model, and larger stems with the core-based model.

A qualitative reconstruction of browsing history was based on a survey of the browsing-related architectures of trees, saplings, and suckers following methods of Keigley and Frisina (1998). A quantitative reconstruction was based on the correlation of stem age and height using belt transect data. A positive correlation would indicate that height growth had occurred as stems grew older; a slope of zero would indicate that height growth had not occurred. To determine if browsing was a significant factor in preventing height growth, we measured the browsing level of all stems 50-150 cm tall to determine if: a) some stems were light-to-moderately browsed, or b) all stems were intensely browsed. A stem was classified as light-to-moderately browsed if, over the life of the primary stem, current-year-growth consistently developed from the annual segment that elongated the previous year (Keigley and Frisina 1998). A stem was classified as intensely browsed if: a) a complete annual segment of the primary stem was dead, and b) that segment had been browsed. The death of a complete annual segment of the primary stem would mean that subsequent growth developed from a segment produced prior to the previous growing season.

Results / Discussion

Belt transect data from the three stands were pooled. There were 292 live stems that were ≤75-cm tall and 30 live stems that were ≥300-cm tall; there were no live stems in the height range 76-299-cm tall (Figure 2). All stems 50-75 cm tall were intensely browsed. Some stems were nipped at about 20 cm high. Nipped branches on saplings indicated that browsing extended to about 250 cm above ground level.

There were no scars on live stems that were ≤ 75 cm tall. The shortest live stem with exposed xylem was 300-cm tall. There were 41 dead stems that were ≤75-cm tall, 26 dead stems that were 76-299-cm tall, and 19 dead stems that were ≥300-cm tall (Figure 3). Out of the 71 dead stems that were ≤300-cm tall, 18 had exposed xylem. The shortest individual with exposed xylem was 80-cm tall and had a stem diameter of 2 cm. No individual with a smaller diameter had exposed xylem. We concluded that a height of 80 cm and diameter of 2 cm were approximate lower limits of height and girth selected for rubbing and gnawing.

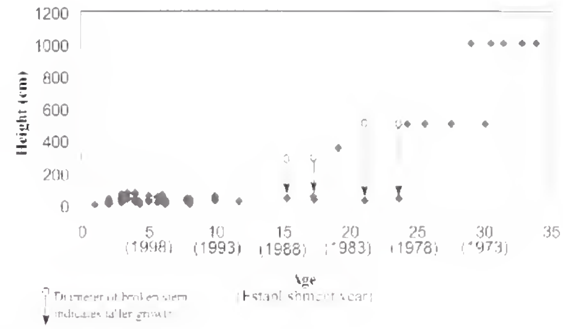

Fig. 2. *Relationship between height and age of live stems. The diamond symbol indicates height measured to the base of current year growth. The circle-and-arrow symbols indicate situations in which the initial stem had died; the diamond indicates the height of the stem that subsequently developed from the base of the initial stem.*

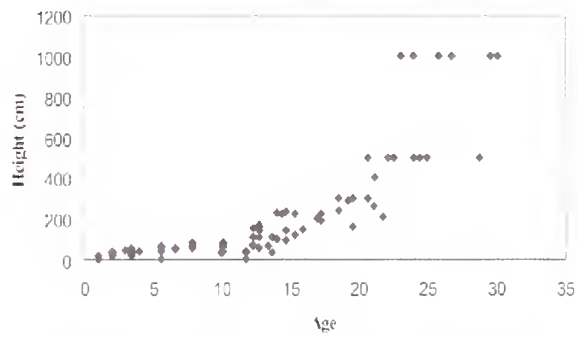

Fig. 3. Relationship between height and age of dead stems. The diamond symbol indicates height measured to the tip of the dead stem. The dotted lines indicate situations in which the dead stem was broken; the dotted lines extend to an estimated height based on the diameter of the broken stem.

The mean maximum height of exposed xylem in the three stands was 171 ± 3, 177 ± 3, and 164 ± 5 cm (±SE) in stands A, B, and C respectively. Pooled data of live sapling stems in the line transects provide an estimate of the upper limit of stem girth selected for rubbing and gnawing (Figure 4). The diameter of live stems sampled in the transects ranged from 5-49 cm; the diameter of dead stems ranged from 3-9 cm. All live stems 5-13-cm diameter had exposed xylem; many of the stems with diameters less than 10-cm were significantly scarred. Bare xylem scars were absent on stems larger than 20-cm diameter with the exception of a very small scar on one 40-cm-diameter individual. All of the dead stems had exposed xylem, suggesting that rubbing or gnawing contributed to their death. We concluded that stems 2-13-cm diameter

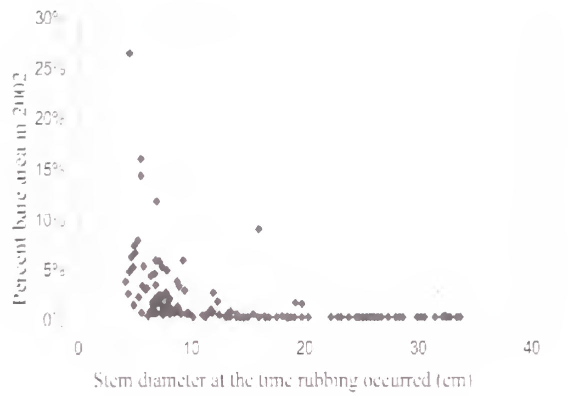

Fig. 4. ***Relationship between stem diameter and percent of the stem area that had exposed xylem: live stems. The stem diameter of unscarred stems was plotted as measured in 2002. The stem diameter of scarred stems was adjusted to the diameter at the time of scarring based on the depth of the deepest furrow. The shaded rectangle cindicates the diameter zone in which all stems were scarred; stems larger than 13 cm diameter were largely unscarred.***

and greater than 80-cm tall were preferentially rubbed or gnawed to the extent that major areas of bare xylem were exposed. Many of the scars appeared to have been produced by bull elk; stems 2-13-cm diameter are a good fit for removing velvet between antler tines

The mean maximum height of rough bark at the three stands was 169 ± 2, 165 ± 1, and 161 ± 2 cm (±SE), respectively (Figure 5). Stems of larger girth had a larger relative area of rough bark compared

Fig. 5. *Compared to small-diameter stems, such as those in Figure 1, large-diameter stems lacked exposed xylem caused by rubbing or gnawing. Stems in this photo range from about 20-50 cm diameter. The black rough bark formed in responsel to injury such as gnawing.*

to smaller stems (Figure 6). The rough bark extended to ground level, a height that was lower than the estimated lower limit of rubbing and gnawing. The formation of rough bark close to the ground may be due to gnawing by voles or injury from blowing snow (Kaufert 1937, Jones and DyByle 1985). The formation of rough bark in the upper region was likely due to gnawing by elk. The larger relative area of rough bark on large stems does not necessarily mean that large stems were selectively used for gnawing. Because the injured area expands as the stem increases in girth, the greater relative area of rough bark on larger stems could be due in part to the increase in girth, with the injury having taken place when the stem was younger. No instance of recent gnawing on rough bark was seen.

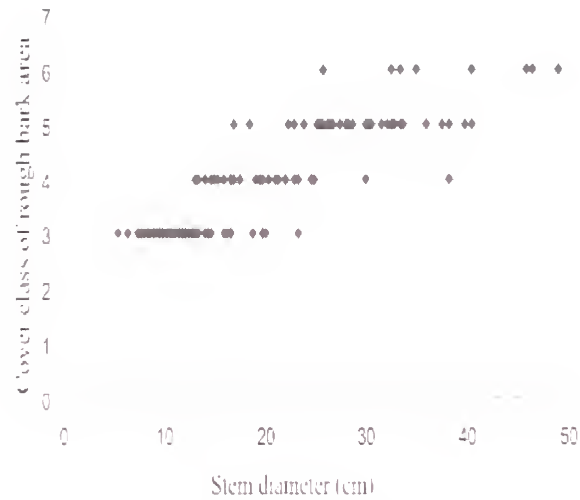

Fig. 6. *Large-diameter stems had a proportionally larger area of rough bark compared to small-diameter stems. Because the area affected by injury expands as the stem increases in girth, much of the scarring may have been produced when the stems were young. Cover classes: 1) 0 - 5%, 2) 6 - 25%, 3) 26 - 50%, 4) 51 - 75%, 5) 76 - 95%, and 6) 96 - 100%.*

The area of exposed xylem on dead saplings >2-m tall was significantly greater than the exposed

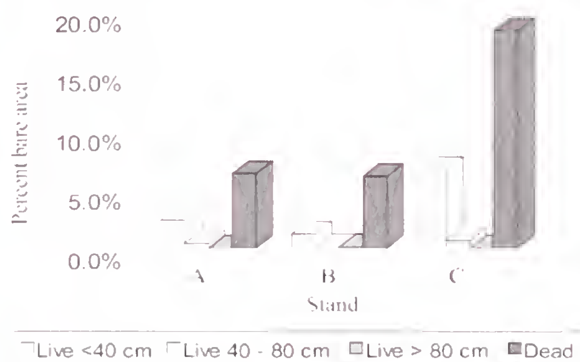

Fig. 7. *Compared to live stems, dead stems had a larger area of exposed xylem suggesting that bark removal was a significant factor leading to mortality.*

area of live saplings (Figure 7). The increased area of exposed xylem on dead stems suggests that rubbing and gnawing contributed to the mortality of those individuals, a finding consistent with that of Miquelle and Ballenberghe (1989). The vulnerability of young stems to injury by rubbing is influenced by two factors. First, small-diameter stems (i.e., <13 cm) are preferentially used for by ungulates for rubbing. Second, a single rubbing event

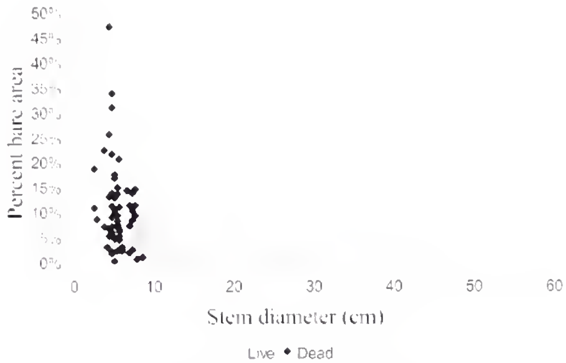

Fig. 8. *Relationship between stem diameter and percent of the stem area that had exposed xylem: live and dead stems. Browsing likely contributed to the death of short stems, while rubbing and gnawing affected taller stems. All dead stems were less than 10 cm diameter.*

proportionally removes more bark from a small-diameter stem compared to a large-diameter stem. A graph of the pooled data of live and dead stems indicates that stems less than 10-cm diameter can be killed by rubbing (Figure 8). The injured bark of stems that were larger than 10-cm diameter had fungal infections that could potentially lead to premature death.

As shown above, rubbing and gnawing by ungulates likely contributed to the death of stems 10-cm diameter. However, stems up to 13-cm diameter were significantly scarred and potentially infected with life-threatening pathogens. Based on a diameter *on* girth correlation model constructed from data pooled from all three stands, a stem would require about 25 years to grow to 13-cm diameter (3 years to grow 1 m tall; 22 years to attain 13-cm-diameter). At this girth the stem is likely to escape significant injury due to antler rubbing in the FWMA study area.

The qualitative history reconstruction indicated that there has been an increase in ungulate use in the study area. Small suckers had arrested-type architecture indicating a current intense browsing level. Saplings and trees had uninterrupted-growth-type architecture indicating that browsing was light-to-moderate in the past.

The correlation between height and age suggests that browsing pressure increased about 1991. No live stem established since that year had grown taller than 75 cm (Figure 2); the mean height of stems in this age range was 54.2 ± 2.1 cm (±SE). All stems 50-150-cm tall were intensely browsed indicating that browsing was a significant factor in suppressing height growth. All live stems established between 1979 and 1991 grew to at least 220 cm tall before being top-killed; it is likely that browsing, rubbing, and gnawing were significant factors in that top killing. While live stems in the 76-349-cm height range were absent, dead stems in this range were common (Figure 3). These individuals were likely killed by browsing, rubbing, and gnawing. We concluded that, prior to 1991 a relatively low level of ungulate use occurred; after 1991, ungulate use increased.

The impacts described above could potentially have been produced by a combination of wild and domestic animals, including elk, livestock, voles, and porcupines. We concluded that elk were primarily responsible because stems were largely unbrowsed during the growing season when livestock were present and because xylem was exposed to heights taller than the body of a cow; those heights were consistent with the height of elk antlers.

The study findings have implications for aspen restoration programs and wildlife management. To encourage regeneration of decadent aspen clones, land managers have cut or burned mature stems to eliminate the source of inhibitory growth regulators. In areas of high ungulate use, treated areas have been fenced, with the intent of removing the fence after stems have grown out of the browse zone. Alternatively, in areas of high elk number, some wildlife managers have considered reducing elk to low numbers, and allow the elk population to increase after aspen stems have grown through the browse zone. This study found that elk inhibit stand regeneration both by the browsing of young suckers and by injury to the stems of saplings. To survive a high level of ungulate use, aspen must be protected not only long enough for the terminal leader to grow through the browse zone, but also long enough for the sapling stem to grow to a diameter that can survive the effects of rubbing. That protection could require on the order of 25 years.

The protection of aspen by fencing could be problematic. We believe that an increase in elk number over a period of years results in a gradual exposure of the bark to gnawing. At low levels of gnawing, aspen develop a rough bark that confers some protection against future gnawing. Where very large numbers of ungulates are present, the removal of a protective fence would suddenly expose tender stems to intense gnawing that could prove harmful.

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Influence of ungulate browsing on skunkbush height growth on the CMR NWR

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Abstract

The purpose of this study was to determine if ungulate browsing prevents young skunkbush plants from attaining full stature. Forty-seven skunkbush shrubs were excavated and aged; browsing level, stem height, stem age, stem growth rate, basal area, and stem number were measured. All shrubs were intensely browsed. The youngest skunkbush collected during stratified random sampling was established in 1984; an individual that was established in 1989 was found in the course of an intensive search for young plants. The mean height of skunkbush plants established during the 1980 - 1989 period was 24.6 ± 2.6 cm. We concluded that browsing prevents young plants from attaining their full stature of approximately 250 cm. Over the past five decades, stem lifespan has declined. A reduction in stem lifespan requires more-frequent production of new stems, a process that may cause physiologic stress. An increase in skunkbush mortality has been documented at two permanent transects located outside the present study area.

A browsing history reconstructed from an analysis of shrub age and shrub height indicated: 1) light-to-moderate browsing prior to 1950, 2) intense browsing from 1950 to late-1960s/early 1970s, 3) light-to-moderate browsing to 1977, and intense browsing since 1978. The reconstructed browsing history corresponded well with skunkbush data collected during previous studies in the area. The reconstructed browsing history was correlated with population data for mule deer and elk. The increase in browsing level in 1978 occurred when 760 deer and 107 elk were present; since 1978 the elk population has increased to as high as 657. Over the past century, fire sensitive plants, such as sagebrush and jniper, likely increased in response to a reduction in fire frequency. The juniper and sagebrush increase the availablity of winter forage. Less abundant, more highly preferred browse species such as skunkbrush may be more sensitive to the effects of browsing by ungulate populations that are currently not limited by winter forage.

Introduction

Background and objectives

This report describes a study of skunkbush (*Rhus aromatica*) in the vicinity of the Sand Creek Field Station of the CMR National Wildlife Refuge (12 676630E / 5275096N). Skunkbush is a shrub that provides food and cover for a variety of wildlife. Mackie (1970) ranked skunkbush second among all taxa in total season use by mule deer (sweetclover ranked number one). The fruit of skunkbush persists over the winter, providing food for other wildlife such as grouse.

Mackie (1970) provides the earliest comprehensive description of the effect of browsing on skunkbush on the CMR. Data collected from June 1960 through September 1963 showed: an average annual available leader use of 58% (range: 40-81%), more than 80% of all plants were severely hedged, and more than 95% were decadent and/or reduced to resprouts.

Mackie (1970) attributed the browsing effects to mule deer, finding minor use by existing populations of elk and livestock. Mackie cautioned that, "*Mule deer, in particular, should be more rigidly controlled by adequate hunter harvests and maintained at levels which will permit regeneration or replacement of deteriorated browse plants and sustainment of deer populations.*" Mackie further cautioned that an increase in elk number was likely incompatible with "*management to sustain forage supplies and populations of mule deer within the present elk range.*" The 1963 mule deer winter trend count was 1000. The winter trend count for elk was 81.

A continuation of the Missouri Breaks mule deer study was described in Hamlin and Mackie (1989). Over the period 1963 to 1983, the canopy coverage of skunkbush in the Pine-Juniper habitat type remained about the same; skunkbush canopy coverage increased significantly in the Douglas fir habitat type. Hamlin and Mackie (1989) concluded that mule deer had no significant effect on skunkbush sumac, and concluded that during the period 1976-1986, that total annual forage quantities of all species were adequate to support 2-10 times the number of deer that occurred on the area during summer and autumn. The mule deer winter trend count for 1986 was 1,355. The winter trend count for elk was 428.

The above conclusion that the range could support more deer was based primarily from the perspective of the ungulate. Namely, can a population of ungulates be supported by the existing forage supply? The ungulate-oriented perspective raises two issues. The first is: How does one evaluate the condition of the forage base as a whole when some species of forage are more sensitive to ungulate use than other species? Forage species that are both less abundant and more preferred can be expected to decline more readily compared to species that are both more abundant and less preferred.

The second issue is: What criteria should be used to measure the condition of forage plants? As suggested above, there are problems in using ungulate health as an indicator of habitat condition, particularly with respect to sensitive browse species. Because heavy browsing over a restricted period of time may induce compensatory growth and sucker-

ing, trend measurements of net productivity and distribution may fail to detect levels of browsing that could ultimately lead to the extirpation. During that period of time, evidence of physiological stress may pass unnoticed.

This study examined how ungulate browsing has affected the stature of skunkbush plants that were established over the past eight decades. The evaluation of data was based on the following premise: If a given species is to persist as a community, some young plants should ultimately attain the stature typical of that species, limited primarily by local environmental conditions. This approach was based on the assumption that we cannot accurately measure the physiological health of browse plants, but if browsing does not prevent the attainment of full stature, then browsing, at least, is not a primary issue of physiological concern.

This study had the following specific objectives:

1) Determine the growth potential of skunkbush at the study site.

2) Determine if browsing prevents young plants from attaining full stature.

3) Reconstruct the browsing history of skunkbush.

4) Determine the relationship between skunkbush height growth and ungulate population size.

5) Determine if skunkbush is in decline.

Skunkbush

Skunkbush in the study area currently range in height from about 20 – to over 200-cm tall. Most plants, such as the one shown in Figure 1 (photographed April 2003), have a hedged appearance due to browsing.

Fig. 1

Skunkbush is a shrub capable of growing to 2.5 meters tall on some sites (Stubbendieck et al. 1986). Because environmental conditions vary with topography and soil, some sites may be more conducive to height growth than others.

Shrubs can become established from seed or from spreading rhizomes. Once established, additional stems develop from the root crown and from short rhizomes, producing a more-or-less compact crown.

The aboveground portion of the shrub consists of a population of stems. Over the life of the shrub, older aboveground stems may die and be replaced by younger stems. Therefore, the shrub may be substantially older than the age of the oldest aboveground stem. An estimated age of the shrub can be determined by counting the number of annual rings in the oldest root or rhizome.

Methods

Sample selection

Three plants were sampled from each of 15 sample sites. The sample sites were located by walking 50 paces parallel to the slope. Samples were stratified into three categories based on basal stem diameter: a) < 1 cm diameter, b) > 1 cm and less than 2 cm, and c) > than 2 cm. At each site, the closest three shrubs meeting those criteria were selected for measurement and sampling. This sample protocol identified 45 shrubs.

Once a shrub was selected, the tallest live stem and the tallest dead stem were selected for height measurement. The height of the tallest live stem was measured from groundlevel to the base of current year growth. This height was recorded as "H_{BCYG}" (BCYG referring to "base of current year growth"). The height of the tallest dead was measured to the tip and recorded as "H_D." Sections were taken from the live stem having the largest basal girth; the location from which those sections were taken is described below. A section was taken from the base of the dead stem having the largest basal girth.

After the above samples were taken, a search was conducted to collect samples of the youngest plants established in the study area. Those plants were collected on the basis of having few stems, all which with small basal girth. Two plants were collected. With these additions, 47 shrubs were examined.

Determine the growth potential of skunkbush at the study site

In areas of high browsing pressure, big game exclosures provide examples of potential stature. Lacking such an exclosure, potential growth can be inferred by examining stem segments that grew in the absence of browsing. The diagram in Figure 2 shows how browsing level varies along the length of a stem. The lower portion of a stem escaped browsing while the stem grew within the mechanical protection provided by older stems. The cluster of twigs formed once the terminal leader grew

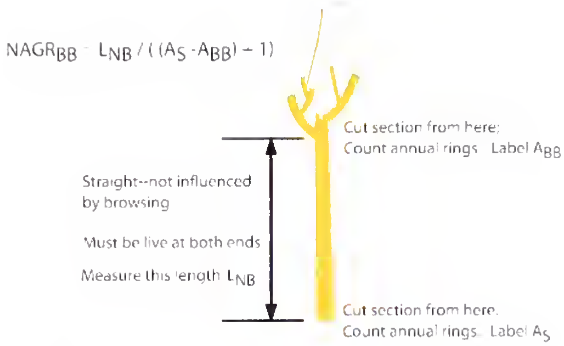

Fig. 2

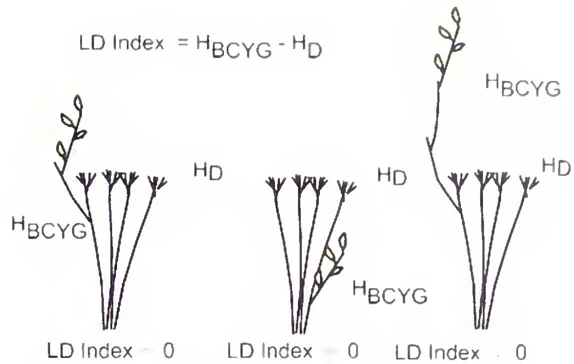

Fig. 3

above the zone of mechanical protection.

$NAGR_{BB}$ is the stem Net Annual Growth Rate before the first browsing event. This growth rate was measured on the live stem having the largest basal girth. The length of the unbrowsed stem segment was measured and labeled L_{NB}. Sections were taken from both ends of the straight segment; the number of annual rings in each section was counted. The age of the section taken from the base of the segment was labeled "A_S"; the number of annual rings in the upper section was labeled "A_{BB}". $NAGR_{BB} = L_{NB} / (A_S - A_{BB} + 1)$. $NAGR_{BB}$ describes the average rate of growth per growing season.

A range of heights to which plants might grow in the absence of browsing was determined by determining $NAGR_{BB}$ and assuming that a stem could grow at this rate for a period of 3 – 5 years.

Determine if browsing prevents young plants from attaining full stature

Measurement of browsing Intensity. The browsing intensity of a shrub was determined by inspecting all stems for evidence of intense browsing. Keigley and Frisina (1998) define a stem to be intensely browsed if a complete annual segment on any stem was dead, provided that segment bore evidence of browsing. Each shrub was classified as being either "intensely browsed" or "light-to-moderately browsed."

Live / Dead Index (LD Index). The shrub was searched to identify the tallest dead annual increment that bore evidence of browsing. The height to the top of that increment was measured and recorded as "H_D." The LD Index = $H_{BCYG} - H_D$. The measurement of H_{BCYG} was described above.

The schematic in Figure 3 indicates how LD Index values are interpreted. Values close to zero indicate that the shrub is being browsed close to the limit of mechanical protection. Values much less than zero indicate that the shrub is dying back to ground level. Values much greater than zero indicate that the plant is growing taller after the most recent episode of intense browsing.

$NAGR_{TAG}$. $NAGR_{TAG}$ characterizes a shrub's net rate of growth based on the height of the tallest live stem (measured to H_{BCYG}) and the age of the oldest live stem. (The subscript "TAG" refers to total aboveground.) The intent of the measurement is to characterize height-made-good of the shrub over the life of the oldest aboveground live stem. $NAGR_{TAG} = H_{BCYG} / (A_S - 1)$.

H_{BCYG} was described in the Sample Selection section above. A_S was sampled from the same stem used to determine $NAGR_{BB}$ (the live stem with the largest basal girth). By measuring $NAGR_{TAG}$ of an older stem, we avoided typifying a shrub's growth history using a young stem that had primarily grown within the mechanical protection of an older canopy.

Since H_{BCYG} does not include height added during the current year, 1 is subtracted to correct for the number of years required for the stem to grow to the height of H_{BCYG}. If a collection were made between the beginning of a calendar year and the beginning of the growing season, the correction would not be made.

A section was collected from the dead stem having the largest girth. The number of annual rings was counted and labeled "A_D." A_D provides one estimate of stem lifespan. A_S provides a second lifespan estimate based on the age of the oldest live stem.

$NAGR_{TAG}$ is used in combination with stem lifespan. The basic question is: given the calculated $NAGR_{TAG}$, do stems live long enough to grow to their potential height?

Reconstruct the browsing history of skunkbush

The browsing history of the site was reconstructed based on an analysis of shrub age and height.

Shrubs were excavated, and the rhizomes or roots with the largest girth were sectioned. The age of each shrub was estimated from a count of annual rings. The hypothetical model described below describes the expected age / height relationships that would occur following an increase in browsing pressure.

If skunkbush shrubs were continuously established during a period of light-to-moderate browsing, the skunkbush community would consist of shrubs of different height. Hypothetical data were used to construct a graph depicting how a light-to-moderately browsed skunkbush community might look in 1970. The data presented in Figure 4 assume that each plant grew at the same rate. In reality, the height of similarly aged shrubs will vary due to a variety of factors including local environmental

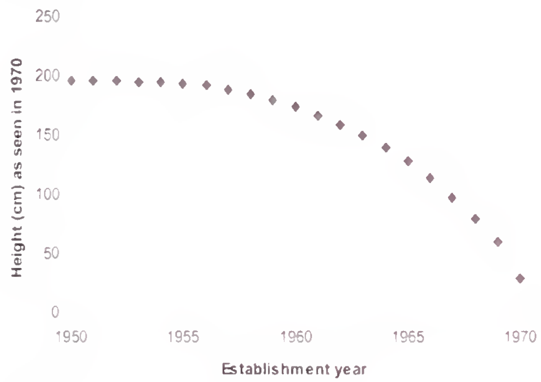

Fig. 4

conditions and genetics.

If browsing became intense in 1970, clusters of twigs would form at the ends of stems. The clusters of twigs form a zone of mechanical protection, within which young stems can grow. As a result, shrubs remain at the height that existed at the time browsing level increased to intense. Shrubs established after the increase in browsing level are browsed 30 cm above ground level. The graph in

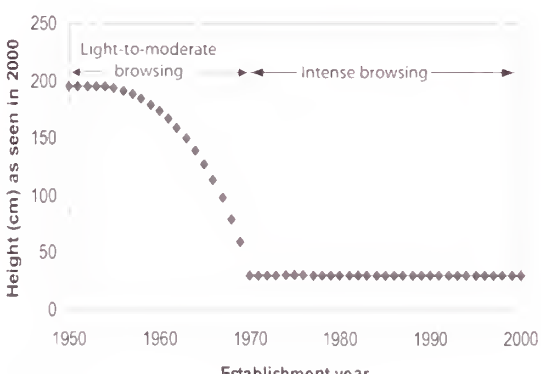

Fig. 5

Figure 5 depicts the age / establishment year relationships as they would appear in the year 2000.

During a period of intense browsing, fire can remove mechanical protection. Stems that sprout from a surviving shrub after the fire are fully exposed to intense browsing. The graph in Figure 6 depicts the establishment year / height relationships of a shrub community in which a shrub that was established in 1960 burned in 1980. By the year 2000, this 40-year-old shrub, which had previously grown to a height of 175 cm, was only able to grow 30 cm tall after the fire. If the fire had occurred in 1965, the shrub would have experienced five years of light-to-moderate browsing, and would have

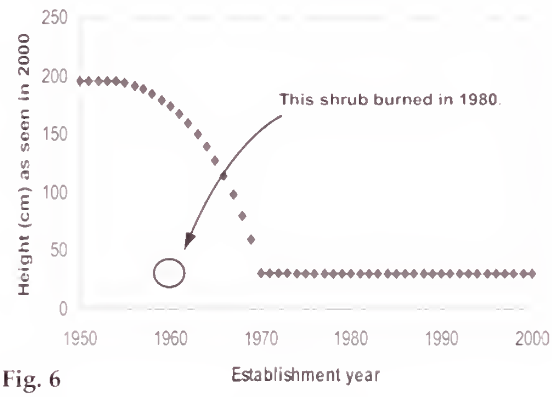

Fig. 6

grown 125 cm tall before browsing increased to intense.

Determine if skunkbush is in decline

Potential decline was examined in two ways. First, as described above, an intense search was undertaken for young skunkbush shrubs. An absence of recruitment indicates potential decline.

We examined the relationships between stem lifespan, shrub age, and shrub height. A reduction in stem lifespan indicates potential decline.

Results / Conclusions

Determine the growth potential of skunkbush at the study site

The mean $NAGR_{BB}$ at the study area was 16 ± 2 cm / year. $NAGR_{BB}$ is a conservative estimate of growth rate. The length of the unbrowsed stem segment is incomplete in that it does not include the portion that was consumed during browsing. In the case of a short stem segment (say 5 cm long), the consumed portion may have been longer than the segment that remains. The consumed portion will be proportionately less in the case of longer stem segments, and for that reason, the measured length of longer segments will more accurately reflect true total stem length compared to shorter segments.

The mean $NAGR_{BB}$ of segments that were greater than 50 cm long was 33 ± 6 cm per year (N = 8).

Skunkbush shrubs that grow at this rate for 3 years would be almost 1 meter tall. In the absence of a big game exclosure, growth during the first three years may offer the best estimate of height-growth potential.

In the study area, some plants have grown over 2 m tall. The tallest plants are found in near the bottom of drainages, indicating that moisture may be limiting factor. While plants growing on drier sites may not attain the height of plants growing on moister sites, it seems likely that in the absence of browsing, those plants could attain heights of 1-to-1.5-meters tall or more.

Does browsing prevent young plants from attaining full stature?

Three approaches were used to examine this question: 1) measurement of browsing intensity, 2) the LD Index, and 3) net annual growth rate.

Measurement of browsing intensity. All plants examined were intensely browsed as indicated by the death of at least one complete annual segment that bore evidence of browsing. In many cases, stems terminated by dense clusters of twigs had died back to ground level. The plants had a hedged appearance similar to that described by Mackie (1979).

Live / Dead Index (LD Index). The LD Index of a shrub is a measure of the shrub's height growth after the onset of intense browsing. A positive value indicates that a living stem has grown taller than the tallest stem killed by browsing. A negative value indicates that the plant is dying back to groundlevel. An LD Index close to zero indicates that stems are being browsed to the zone of mechanical protection.

The mean skunkbush LD Index in the study area was –5.4 ± 2.0 cm, with a maximum of 36 cm and a minimum of –55 cm. As can be seen in Figure 7, the

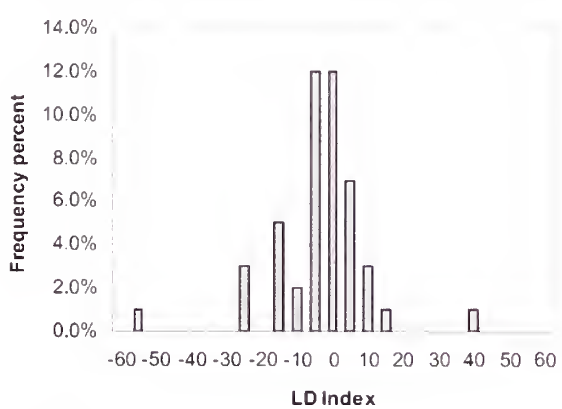

Fig. 7

maximum and minimum LD Index values are outliers.

The mean value of -5.4 indicates that stems are being browsed to the zone of mechanical protection, and indicates that browsing prevents height growth. Browsing to the zone of mechanical protection produces a hedge-like growth form.

$NAGR_{TAG}$. The mean $NAGR_{TAG}$ for all plants was 5.0 ± 0.4 cm per year, with a maximum of 12 and a minimum of 1.3. At a mean rate of 5 cm per year, a stem would have to live 40 years to attain a height of 200 cm. The average age of the 20 oldest dead stems was 20.0 ± 0.7 years; the maximum age was 29 years. The average age of the 20 oldest live stems was 20.8 ± 0.6 years; the maximum age was 26 years. The mean $NAGR_{TAG}$ for all skunkbush shrubs suggests that under the current browsing pressure, none will live long enough to grow to 200 cm tall. The growth of some shrubs to 200-cm tall indicates that browsing pressure must have been lower sometime in the past.

The seven shrubs established after 1978 have experienced 15 - 20 years of consistent intense browsing. The average height of these plants was 24.6 ± 2.6 cm. The $NAGR_{TAG}$ of those shrubs was 5.9 ± 1.5 cm per year. At this rate, it would require 25 years to grow to a height of 1.5 meters. The mean age of the oldest dead stems on these shrubs was 7.7 ± 0.8 years; the maximum age of dead stems was 12 years; the oldest live stem was 10 years old. Those lifespan data indicate that stems will not survive long enough to grow to 1.5 m tall.

Will some young plants attain full stature? The average height of plants established during the period 1980 – 1989 was 24.6 ± 2.6 cm tall (N= 7), with a maximum height of 34 cm and a minimum of 16 cm. Based on an $NAGR_{BB}$ of 33 cm per year, skunkbush plants established during that period should have attained a height of 1 meter within three years and grown to even greater heights in the following 15-25 years. The LD Index of these plants was -3.4 ± 0.1 cm, indicating that browsing has prevented the height-growth of these plants.

All of the approaches described above indicate that browsing prevents young plants from attaining full stature, and prevents older plants from growing taller.

Reconstruct the browsing history of skunkbush

The graph in Figure 8 plots the year that a shrub was established on the X-axis and the height of the shrub's tallest stem (maximum of live and dead) on the Y-axis.

Skunkbush established during the past two

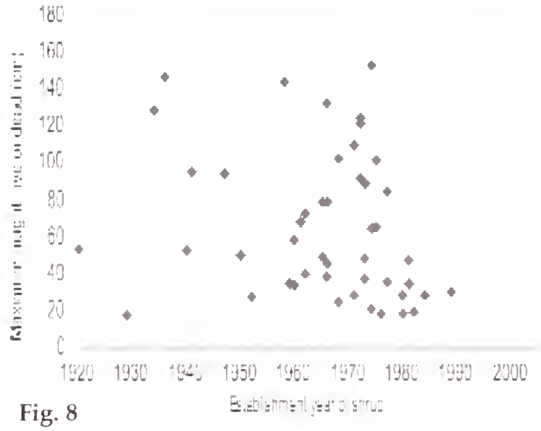

Fig. 8

decades have failed to grow taller than 31 cm. Even a conservative estimate of $NAGR_{BB}$ indicates that, in the absence of browsing, skunkbush could have attained much greater heights over two decades. Growth restricted to 30 cm is a benchmark that describes the ability of young skunkbush to grow under the existing conditions of intense browsing.

Browsing would not prevent height growth in plants established during periods of light-to-moderate browsing. If light-to-moderate browsing persists for a period of years, the skunkbush community would consist of plants of different age, with the older plants being taller than younger plants.

If browsing intensity increased to an intense level, further height growth would cease. The development of a hedge-like crown would mechanically protect young stems that grow within the interior of the shrub; these stems would be browsed once they exceeded the zone of mechanical protection. As a result, after years of intense browsing (and in the absence of fire), the skunkbush community would consist of plants of different age, the heights of which would reflect the heights that existed at the time browsing pressure increased to intense.

The data have a bimodal distribution that is

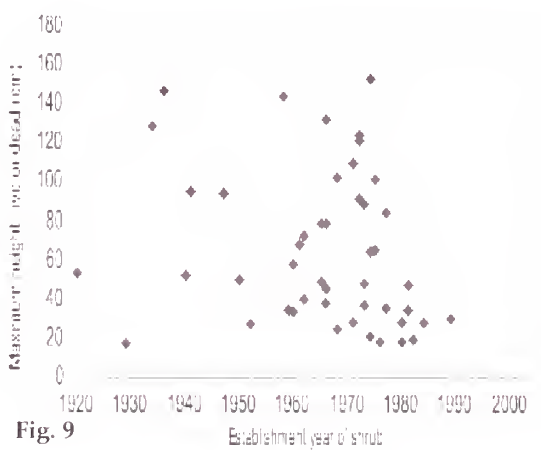

Fig. 9

depicted by the curved lines in the graph in Figure 9. In some cases, the height of shrubs established within a given year varies significantly. In part, this variation is due to local growing conditions. Fire is another factor affecting current stem height. Fire scars were common in the study area, with one scar dated to 1985. Fire may have killed stems that grew tall under light-to-moderate browsing levels, forcing new stems to grow under intense browsing that began in 1978.

When plotted on a graph in which establishment year increases to the right, an inverse relationship between establishment year and height results in a negative slope. The graph in Figure 10 shows two negative slopes that correspond to the negative slope on the curves shown in Figure 9. If the plants were relatively young, an inverse relationship between height and age would be expected due lack of maturity. But when the plants are old enough to have attained full stature, the negative slope indicates that something abruptly inhibited height growth. The negative slopes in Figure 10 are

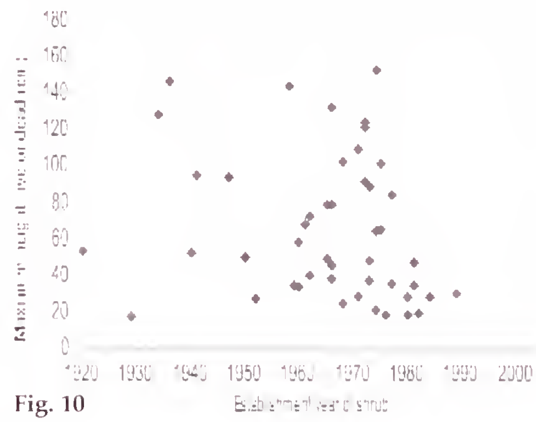

Fig. 10

interpreted to have been produced by two separate increases in browsing level.

The $NAGR_{BB}$ of plants about 1 m tall was used to estimate the onset years of intense browsing. As a plant ages, its growth rate declines. Plants one meter tall are assumed to still be in a rapid phase of growth. If a one-meter-tall stem grew at a $NAGR_{BB}$ of 33 cm per year, the stem would attain a height of one meter in three years. Using this criterion to estimate timing, the graph in Fig. 11 indicates two onset years of intense browsing: 1950 and 1978. These years do not indicate an abrupt increase in browsing pressure that affected every plant in the same way, but they do provide a means of correlating changes in plant growth to changes in ungulate population size.

The occurrence of two separate onsets of intense browsing indicates a four-part history:

1) A period of light-to-moderate browsing that pre-

ceded the onset of intense browsing that occurred in 1950.

2) A period of intense browsing that began in 1950.

3) A period of light-to-moderate browsing that preceded the onset that occurred in 1978.

4) A period of intense browsing that began in 1978 and continues to the present.

Below we describe corroborating evidence for this history and describe how we determined the duration of the period of light-to-moderate browsing that ended in 1978.

During the 1920s and 1930s, deer numbers were very low. During that period, browsing would have been light compared to the current level, allowing skunkbush to grow taller than 30 cm tall.

The post-1950 period of intense browsing is consistent with the description of skunkbush by Mackie (1970): 58% leader use, more than 80% of plants severely hedged, and more than 95% being decadent and/or reduced to resprouts. The Mackie (1970) data were collected during the period 1960 - 1963. Based on the present effect of browsing, plants established during this period would fail to grow taller than 30 cm.

As can be seen in Figure 11, some plants established during the period 1960 – 1978 have grown substantially taller than 30 cm. This growth must have occurred during the period of light-to-moderate browsing that preceded the increase that occurred in 1978. Below we describe how we determined the duration of that period, and describe corroborating evidence from Hamlin and Mackie (1989).

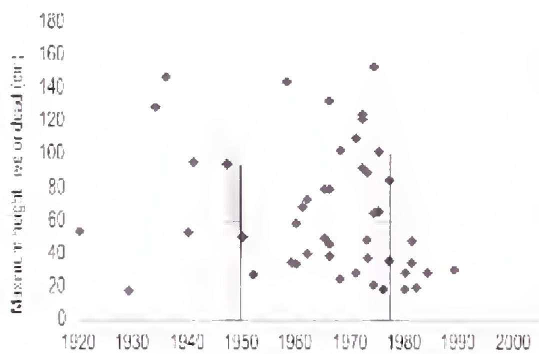

Fig. 11

We estimated a beginning year of the light-to-moderate-browsing period by: a) calculating the number of years it would take the tallest plant to attain its height, and b) assuming that further height growth ceased in 1978. We estimated the required number of years using measured $NAGR_{BB}$ values. As a plant ages, its growth rate diminishes, so we considered the value of 33 cm per year (based on stem segments > 50 cm long) to be maximum. As described above, we believe the overall mean $NAGR_{BB}$ of 16 cm per year to be conservative. We believe that the actual mean growth rate lies within a range of 16 – 33 cm per year.

Using the estimated $NAGR_{BB}$ range of 16 – 33 cm per year, the 154 cm tall shrub established in 1974 could have attained its maximum height in 9 - 5 years. That interval is indicated in the browsing history presented in Figure 12 Hamlin and Mackie (1989) document a significant decline in skunkbush

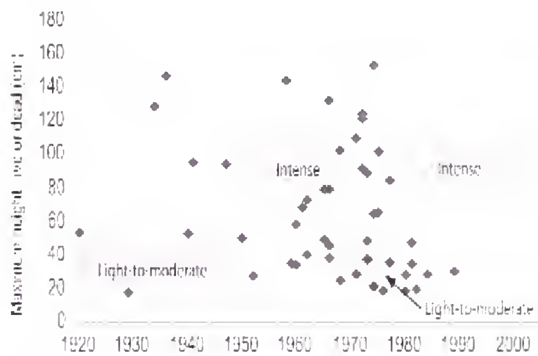

Fig. 12

utilization that occurred during the mid-1970s. That reduction in utilization corresponds with height growth of stems in the mid-1970s documented by our study. In 1982 and 1986, Hamlin and Mackie remeasured plots established by Martin (1972), and found that plant diameter, area, and volume were greater in 1982 and 1986 compared to the measurements made by Martin in 1971. The measurements made in 1971 reflect the previous 21 years of intense browsing. The measurements made in 1982 and 1986 followed the period of light-to-moderate browsing documented by our study.

Hamlin and Mackie (1989) found that skunkbush height measured in 1986 was significantly lower than height measured in 1982. Based on the reconstructed browsing history developed above, plants in 1982 were experiencing intense browsing. By 1986, those same plants experienced an additional four years of intense browsing. Our data document the effect of browsing in the mid-1980s by the failure of two plants established 1980 to grow taller than 18 and 27 cm, respectively.

Some plants that were established during and prior to the period of light-to-moderate browsing failed to attain significant height. The potential reasons for the reduced growth are: 1) heavy livestock grazing that continued until 1991, 2) fire subsequent to 1978 that removed mechanical protection, and 3) for stems that developed in the mid-to-late-1960s, physiological stress during the period of intense browsing by deer and livestock.

Explore the relationship between skunkbush condition and ungulate population size

The graph in Figure 13 integrates the history of browsing with the number of deer present during the winter. The graph is based in part on Hamlin and Mackie (1989) and in part from data furnished by Tom Stivers, MFWP, Lewistown, MT

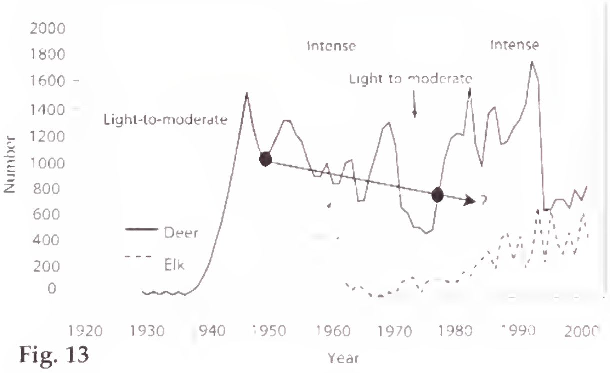

Fig. 13

The descending horizontal line connects points denoting the number of deer present at the time browsing level changed from light-to-moderate to intense. For example, 760 deer were estimated to be present during the winter when the onset of intense browsing occurred in 1978.

In the mid-1990s, deer numbers declined below 900. The reconstructed history described above indicates that the height growth of skunkbush should have resumed, yet skunkbush established during the past two decades have failed to grow taller than 31 cm. Since the 1980s, elk numbers have increased markedly. The failure of skunkbush to grow in the presence of low deer numbers may, in part, be due to an increase in elk number. In addition, as the skunkbush community declines, deer and elk direct their focus on a dwindling supply of surviving plants.

Determine if skunkbush is in decline

The graph in Figure 14 is a plot of the maximum age of either live or dead stems versus the maximum height of either live or dead stems. Stem lifespan was positively correlated with the height of the shrub ($R^2 = 0.45$, $P < 0.0001$, $N = 47$). The mean stem lifespan of shrubs taller than 50 cm was 17.9 years ($N = 21$), while the mean stem lifespan of shorter shrubs was 11.9 ± 0.9 years ($N = 26$).

For shrubs established since 1978, neither the oldest live nor the oldest dead stems was as old as the respective shrubs on which they grew (see Figure 15), indicating that there has been a complete turnover in stems since these shrubs were established. The required regrowth of new stems may be physiologically stressful and result in mortality.

Data collected elsewhere suggests that there has

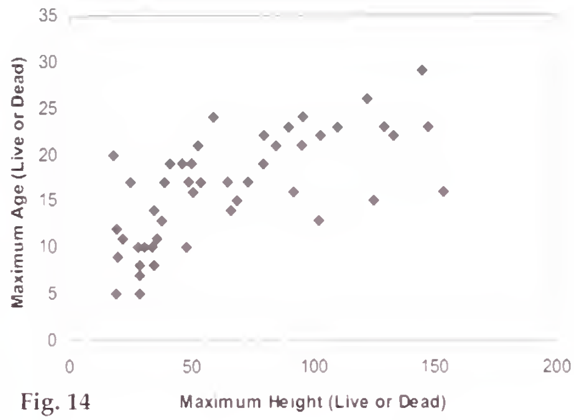

Fig. 14

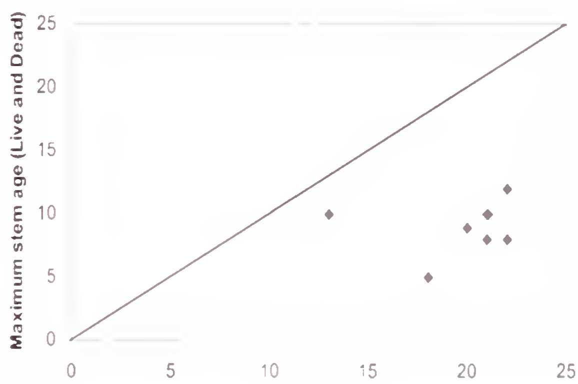

Fig. 15

been extensive mortality of skunkbush. Two skunkbush transects were established on the CMR in 1973, one at the Hell Creek Site on the CMR (47° 37′ 9.5″ 106° 54′ 5.3″), the other at the Doug Watts Ranch site adjacent to the CMR north of Jordan, MT. In 1973, 100% of the sampled plants at the Hell Creek site were alive (80% were decadent). In 1998, 84% of the plants were dead (unpublished data collected by Bernie Hildebrand, MFWP). At the Watts Ranch site, 100% of the plants were alive in 1973; in 1998, too few plants were present to sample (unpublished data collected by Bernie Hildebrand, MFWP).

The findings of this study suggest that browsing may reduce the production of skunkbush fruit. Flowers are produced at the tips of stems. The LD Index value of -5. 4 indicates that those tips that extend beyond the limit of mechanical protection are frequently browsed, along with any flower-producing bud that may be present. Some flowers do develop in the interior of the canopy where they are mechanically protected.

The youngest shrub sampled in the course of stratified random sampling was established in 1984. In an intense search for younger shrubs, an individual was sampled that was established 1989. This individual was growing in shelter of juniper. On the open slopes that comprise skunkbush habi-

tat, there has apparently been no recruitment since the mid-1980s.

Because our data collection was stratified by basal girth of live stems, the collected data are not suitable for determining the age structure of skunkbush in the area. Many of the samples collected were established during the period of the Martin (1972) and Hamlin and Mackie (1989) studies. The recruitment documented by the Hamlin and Mackie (1989) study is consistent with our data. The absence of recruitment since the mid-1980s may be due to a browsing-related reduction in fruit production and a reduction in vegetative reproduction due to browsing-related physiological stress.

Shrubs that were able to attain some height in the mid-1970s are likely to be less sensitive to the effects of browsing compared to younger, shorter plants. Over the long term, these taller plants will eventually die; fire could quickly remove the mechanical protection that deters the browsing of stems in the interior of the shrub. If recruitment continues to occur at a negligible rate, skunkbush could disappear from the local plant community.

A Hypothetical Model

Two features characterize the present ecological condition: 1) an increase in forage that allows deer to survive the winter, and 2) a decline in skunkbush (and likely other species of browse and forbs) due to browsing. If ungulate populations were in balance with the plant communities over the long term, there should be no browsing related declines. The following hypothetical model may explain how the present conditions developed.

It is commonly accepted that there has been a reduction in fire frequency over the past several decades. In part, fire frequency may have been reduced since the late 1800's when heavy livestock grazing removed fine fuels. Fire suppression since the mid-1900's also contributed to reduction in fire frequency. Its seems reasonable that species sensitive to fire such as juniper and big sagebrush increased as species responsive to fire such as skunkbush decreased. Large numbers of domestic sheep and cattle that grazed the range during the late 1800's and early 1900's probably contributed to the decline in more-highly-preferred plant species such as skunkbush. While we may speculate about the number of deer present during the time of Lewis and Clark, we do know that deer were relatively scarce during the early part of the 1900's. The increase in deer in the late 1930's was coincident with the likely increase in juniper and sagebrush and decrease in skunkbush due to fire suppression and the large numbers of domestic sheep and cattle grazing the range. In addition, the increased number of deer would place pressure on the more-highly-preferred skunkbush, which may have been already relatively scarce compared to juniper and big sagebrush.

In 2003, from the perspective of the ungulate, there may be sufficient browse not only for survival, but also for an additional increase in numbers. But from the perspective of skunkbush, the situation is not optimistic. With the exception of an interlude in the 1970's, browsing has inhibited the height growth of skunkbush for more than five decades. Under current browsing conditions, young skunkbush plants grow no taller than about 30 cm. While new skunkbush plants were established regularly over the period 1960 - 1985, recruitment since that time appears to be uncommon. Short-lived stems on young plants and documented mortality of plants elsewhere on and near the CMR suggest and increase in mortality. Based on the existing evidence, it is open to question whether skunkbush can persist given the existing level of browsing.

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Keying In on Big Sagebrush


Attitudes regarding big sagebrush communities are changing from favoring their destruction to promoting their conservation. Left photo courtesy of the Twin Falls, Idaho Public Library, Bisbee Collection.

A guide for identifying the four subspecies of big sagebrush.

By Michael R. Frisina and Carl L. Wambolt

Interest in sagebrush plant communities has intensified due to national concern about wildlife associated with them. Sage-grouse and other native fauna closely associated with sagebrush plant communities are thought to be declining in many areas. Several range-wide petitions have been filed for listing the sage-grouse under the Endangered Species Act. The black-tailed prairie dog, often associated with sagebrush-grass types, and the sagebrush dependent pygmy rabbit are also said to be in decline.

Although the landscape of the western United States is commonly typified by diverse sagebrush flora, there is a long standing attitude in the West that takes sagebrush plant communities for granted or considers them little more than a hindrance to agricultural uses. This is especially true of big sagebrush, the most common and widely distributed sage species in the western United States. Slowly this attitude is changing to one of concern for the conservation of sagebrush plant communities.

Over the years, those interested in the management of sagebrush habitats have asked us for tools they can use in the field to better identify the diverse sagebrush taxa (5).This paper provides an aid in the form of photographs and descriptions for identifying four generally accepted subspecies of big sagebrush. We chose to discuss big sagebrush as it is the species most often at the center of controversy due to frequent proposals to kill it by burning, spraying, or plowing. Our purpose is to aid the field investigator with identification. We also contrast the ecological characteristics of the big sagebrush subspecies. Our approach closely follows Wambolt (3), Wambolt and Frisina (4), and Wambolt and Frisina (5).

Sagebrush taxa occur on an estimated 109 million ha in the region (1,2). Many sagebrush taxa are habitat type dominants strongly associated with native fauna. The genus (*Artemisia*) and species (*tridentata*) for big sagebrush were first described by Nuttall in 1841 based on a specimen he collected on the Snake River Plain of Idaho. Later taxonomists divided big sagebrush into the four subspecies we discuss while some recognition has been provided for even further separation within big sagebrush.

Although different subspecies of big sagebrush may occasionally be found growing together, generally they require different environmental conditions. Table 1 contrasts the environmental requirements of big sagebrush to provide insight to the ecological variation existing among the many communities occupied by big sagebrush.

Basin Big Sagebrush

It has often been stated that the land occupied by basin big sagebrush could be farmed. That is generally the case because this subspecies occupies deep well-drained soils usually found in valley bottoms or other locations where such soils occur.

Table 1. Habitat relationships of the 4 subspecies of big sagebrush (*Artemisia tridentata*).

Common Name	Basin big sagebrush	Wyoming big sagebrush	Mountain big sagebrush	Subalpine big sagebrush
Scientific Name	*A. t. tridentata*	*A. t. wyomingensis*	*A. t. vaseyana*	*A. t. spiciformis*
Range[1]	11	11	10	5
Soils	Deep, Well drained	Shallow clay, Xeric, Sometimes silt	Variety	Mesic
Precipitation[2]	1	1	2	2
Relative[3] browsing tolerance	L	L	L	M
Relative fire[3] tolerance	L	L	L	M
Height[4] at maturity (dm)	Large	Medium	Medium	Medium
Vegetative reproduction	No	No	No	Yes

[1]Number of states within the 11 western states (WA, OR, ID, MT, CA, NV, UT, WY, CO, AZ, NM)
[2]1=25-36 cm (10-14 in.), 2=>36 cm (>14 in.)
[3]L=low, M=moderate
[4]Exclusive of inflorescences. Medium=4dm to 1 m (16-39 in.), Large=>1m (>39 in.)

Mountain Big Sagebrush

Mountain big sagebrush, like basin big sagebrush, requires more moisture than does the Wyoming subspecies. However, mountain big sagebrush usually obtains its moisture by growing in localities with greater amounts of precipitation rather then occupying very deep soils favored by basin big sagebrush. Soils occupied by mountain big sagebrush range from sandy through silty and clayey textures, and may often be cobbly. However, generally finer textured soils appear to be favored by the taxon. Compared to surrounding upland community types, mountain big sagebrush usually occupies the deeper more mesic locations.

Wyoming Big Sagebrush

At the other end of the habitat gradient among big sagebrush taxa, Wyoming big sagebrush occupies the most xeric locations. These sites are usually the product of shallower soils and a large amount of clay or sometimes silt in the soil profile. Wyoming big sagebrush does not do well on course-textured soils.

Subalpine Big Sagebrush

The fourth subspecies, subalpine big sagebrush, was originally considered a high elevation form of mountain big sagebrush. Subalpine big sagebrush is the only subspecies known to commonly root-sprout. Because subalpine big sagebrush generally occurs at elevations above traditional big game winter ranges, it is not usually heavily browsed.

Summary

Ability to identify the four subspecies of big sagebrush provides the land manager with insights into the ecological characteristics of the site and habitat needs of associated wildlife.

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Basin big sagebrush lightly browsed on the left and heavily browsed on the right. Basin big sagebrush is a tall plant standing 1 to 3 m at maturity. Flowerstalks in panicle form arise throughout a relatively uneven crown.

Leaves are long in relation to width and wedge shaped.

Ode to Sagebrush

© R. Margaret Frisina

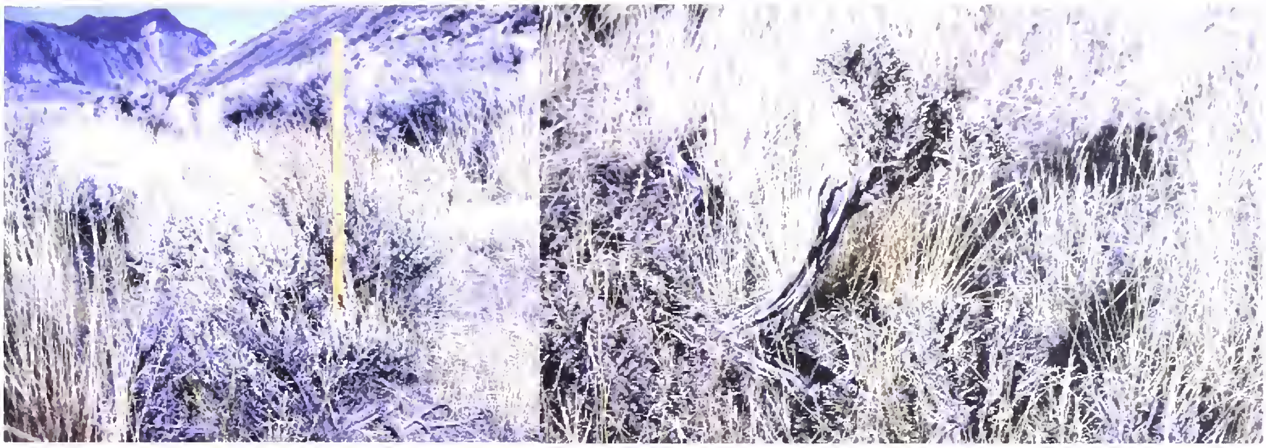
your spreading branches keep grazers at bay
provide sheltering nests, shade from heat of the day
an evergreen nursery for young of all ilk
nurturing life forms from insects to elk
feed hungry wildlife in times of deep snow
water the forbs that around your base grow
anchor the soil so that none blows away
add color and scent to the dawn of each day
secret the sage-grouse and curtain their dance
provide perfect cover for upland romance
reminder of rangelands in wide-open days
of what we will lose if we keep up our ways
for despite all the good you unquestionably do
we just seem intent to eradicate you
in the name of improvement we burn you right out
"Better habitat for wildlife," some of us tout
"My cattle don't eat it," others say
"Another damn weed! It gets in my way!"

but all of that argument just isn't true
livestock, you see, will use sagebrush, too
for food and for shelter out on the range
livestock and wildlife – it isn't so strange

but the once mighty Sagebrush Sea of the past
is now merely a trickle, just puddles at best
with the fate of sage goes our wildlife bequest
the wildness that was
the soul of the West

Mountain big sagebrush lightly browsed on the left and heavily browsed on the right. Mountain big sagebrush are generally less than a meter tall with flower stalks in panicles arising to nearly even lengths above foliage. Found on a variety of soils receiving precipitation levels associated with mountains and foothills.

Leaves intermediate in length-to-width ratio.



Wyoming big sagebrush lightly browsed on the left and heavily browsed on the right. Wyoming big sagebrush are generally less than a meter tall with flower stalks in a relatively compact crown.

Leaves
bell shaped with
bases strongly
tapered.

Subalpine big sagebrush usually occurs at elevations (>2,100 m) above most big game winter ranges and as a result is normally lightly browsed. Plants are generally less than a meter tall with large leaves and a relatively open crown.

Douglas-fir's effect on mountain big sagebrush wildlife habitats

Adam J. Grove, Carl L. Wambolt, and Michael R. Frisina

Abstract: Control of establishing conifers to lessen their impacts on understory is a contentious habitat issue throughout the western United States. Our objective was to model the effect of increasing Douglas-fir (*Pseudotsuga menziesii*) canopy cover on mountain big sagebrush (*Artemisia tridentata vaseyana*) canopy cover. We sampled 25 sites, representing different levels of Douglas-fir establishment, within each of 3 southwestern Montana mountain big sagebrush communities. Over all sites, Douglas-fir canopy cover had a significant correlation ($r = -0.86$; $P < 0.001$) to mountain big sagebrush canopy cover. Regression models were variable among study-areas as linear and curve-linear declines in mountain big sagebrush canopy cover were found. While model validation results indicated that individual study area models were marginal for predicting relationships for the other study areas, the overall model developed from all sites combined generally predicted individual sites well, especially when mountain big sagebrush cover was <15%. Mountain big sagebrush canopy cover declined from >20% to <15% and <5%, as Douglas-fir canopy cover increased beyond 20% and 35%, respectively. At least 92 species of mammals and 93 species of birds having either an obligatory or facultative relationship with sagebrush are affected to differing degrees by loss of sagebrush cover.

Key words: *Artemisia tridentata vaseyana*, canopy cover, conifer establishment, Douglas-fir, mountain big sagebrush, *Pseudotsuga menziesii*, wildlife habitat.

Douglas fir (*Pseudotsuga menziesii*) and other conifers often establish on sagebrush (*Artemisia*)-dominated rangelands in the western United States (Gruell et al. 1986). Arno and Gruell (1983) indicated that prior to fire suppression, Douglas-fir often was restricted to moist sites, rocky outcrops, and talus slopes. However, overgrazing (Vale 1975), changes in the microenvironment (Strang and Parminter 1980), changes in climatic conditions (Patten 1963), as well as fire suppression (Sindelar 1971; Arno and Gruell 1983, 1986) may cause conifer encroachment. Conifer encroachment often is perceived negatively (Arno and Gruell 1986, Gruell et al. 1986); however, Strang and Parminter (1980) regarded encroachment of trees into rangelands as a natural process fostered by human activities and observed that its perception as positive or negative depended on management objectives.

Establishment of Douglas-fir in mountain big sagebrush (*Artemisia tridentata vaseyana*) communities leads to new management decisions. Establishing Douglas-fir may provide additional security and thermal cover for wild ungulates and other fauna foraging in mountain big sagebrush communities. The issue for these animals becomes, "At what level of Douglas-fir establishment is the benefit of additional cover exceeded by the loss of forage, particularly browse on winter ranges?" Because mountain big sagebrush and associated species are important wildlife forage (Wambolt 1996, 1998; Welch 1999; Connelly et al. 2000), prediction of when the cover benefits of Douglas-fir are exceeded by the loss of big sagebrush is important for optimizing habitat for these species. However, some animals, especially sagebrush obligates like sage-grouse (*Centrocercus urophasianus*), may experience negative impacts at lower levels of conifer establishment before sagebrush loss significantly affects forage supply. This knowledge will inform management of at least 92 and 93 species of mammals and birds, respectively, with varying levels of dependence on sagebrush (Welch, 2005).

Our objective was to quantify the effect of Douglas-fir establishment on mountain big sagebrush. To do this we developed regression models to predict effects of different levels of Douglas-fir canopy cover on mountain big sagebrush canopy cover.

Study areas

We located 3 study areas within mountain big sagebrush communities in southwestern Montana. Each contained 25 30.5-m x 30.5-m sampling sites that collectively contained a continuous range of Douglas-fir cover classes from 0 to >60%. There was no evidence indicating that any of the sampling sites had been burned, sprayed, or logged, although long- term grazing of cattle has occurred at all sites.

The Sugarloaf Mountain (SLM) study area was part of the Boulder Batholith formation in Jefferson County, 6 km northeast of Boulder. Sites ranged in elevation from 1,792-1,871 m, slopes from 6-17°, and aspects from NE-S. Annual precipitation of 357- 406 mm peak between May and July (Caprio et al. 1994). The soil was classified as a sandy, mixed Typic Cryoboroll (Soil Survey Staff 1994). The

Medicine Lodge Peak (MLP) study area was in the foothills of the Beaverhead Mountains 24 km south of Grant in Beaverhead County. Sites ranged in elevation from 2,231-2,286 m, slopes from 7-18°, and aspects from WNW–NNE. Annual precipitation was similar to the SLM study area (357-406 mm) with most occurring from April–July (Caprio et al. 1994). The soil was classified as a clayey-skeletal, mixed Argic Cryoboroll (Soil Survey Staff 1994). The Hells Canyon (HC) study area was located in the foothills of the Highland Mountains about 20 km northwest of Twin Bridges in Madison County. Sites ranged in elevation from 2,134-2,280 m, slopes from 5-18°, and aspects from NEE–SSW. Annual precipitation of 254-305 mm peaked April through July (Caprio et al. 1994). The soil was a coarse-loamy, mixed Argic Cryoboroll (Soil Survey Staff 1994). The dominant understory species at all 3 sites were Idaho fescue (*Festuca idahoensis*) and bluebunch wheatgrass (*Pseudoroegneria spicata*) among 57, 55, and 64 total species at the SLM, MLP, and HC areas, respectively.

Methods

We subjectively selected 25 study sites within each study area to sample across a continuum of Douglas-fir establishment levels from low to high. We avoided areas showing severe livestock impacts such as bedding areas. We measured Douglas-fir and mountain big sagebrush canopy cover at each sampling site (n = 75) using the line-intercept method (Canfield 1941) along 6 stratified 30.5-m transect lines placed approximately 5 m apart on a 30.5-m baseline transect. We measured Douglas-fir and mountain big sagebrush live growth in 3-cm increments. We did not include gaps in the canopy $\geq$3 cm. We placed a metal rod perpendicular to the transect line to determine where Douglas-fir intercepted the line.

We used site means, averaged over the 6 line transects, in all statistical analyses (n = 25 per study area). We developed a regression model for each study area and a combined model from all sites (n = 75) in the 3 study areas. The dependent variable was mountain big sagebrush canopy cover and Douglas-fir canopy cover was the independent variable.

We produced correlation coefficients between Douglas-fir canopy cover and mountain big sagebrush canopy cover using PROC CORR (SAS 1988). We plotted Douglas-fir canopy cover against the mountain big sagebrush canopy cover to determine whether a curve-linear relationship existed. We added a quadratic term to the regression model for sites where a potential curve-linear relationship existed. While some models contained a quadratic term, all models were linear in form with no regression coefficients as exponents (Neter et al. 1996).

We ran models for sagebrush canopy cover (PROC REG [SAS 1988]) using both Douglas-fir canopy cover and the square of this variable in the model. We determined the best-fit model by evaluating the Press_p statistic for each model. We selected the model with the lowest Press_p statistic. The Press_p statistic measures how well the fitted values for a given model predict the observed response values (Neter et al. 1996).

We determined the presence of any highly influential observations by examining studentized residuals to detect outlying response values, Cook's D values to determine influence on all fitted values, DFFITS values to determine influence on a single value, and DFBETAS values to determine influence on regression coefficients (Neter et al. 1996). We omitted an observation that was highly influential overall in a best-fit model and ran the model without that observation. We considered an observation highly influential if dropping it from the model resulted in an average change of >5% in the fitted values.

We validated the best-fit models by comparing the 80% prediction intervals for an individual observation with the observed values from the other study areas. We generated the 80% prediction intervals by rerunning the models with the statistical package MINITAB (1996). We determined the linear correlation (r) between predicted and observed values using PROC CORR (SAS 1988).

In addition to developing individual best-fit models for each of the 3 study areas, we determined an overall best-fit model by combining data from the 3 study areas. The best-fit overall model was developed by the same method as that used for the individual study areas. The initial overall model was a validation model based on only 60 sites. Model validation may be done by splitting a data set (Neter et al. 1996), so we removed a random sample of 15 observations from the data set prior to the validation process. We then validated the overall model by the same method used for the 3 individual study areas. After the validation model was derived, we ran the model with all 75 sites to determine the full model.

Results

Where Douglas-fir canopy cover increased, mountain big sagebrush canopy cover decreased (P < 0.001) in the SLM (r = –0.82), MLP (r = –0.91), and HC (r = –0.92) study areas and over all sites (r = –0.86) in a curvilinear manner except at the SLM study area (Table 1). The importance of the solitary predictor variable, Douglas-fir canopy cover, in influencing mountain big sagebrush canopy cover

Table 1. Regression models for predicting mountain big sagebrush canopy cover (%) using Douglas fir canopy cover (%) as the independent variable at each of the 3 southwestern Montana study areas and over all 3 areas from sampling conducted during 1996 and 1997.

Study area	Model	R^2_a	MSE
SLM[a,b]	Sagecc[c] 3.1 - 0.051DFCC	0.85	0.11
MLP	Sagecc = 23.2 − 0.711DFCC + 0.005DFCC^2	0.89	7.0
HC	Sagecc = 23.8 − 0.636DFCC + 0.004DFCC^2	0.86	7.4
Full model over all[a] sites	Sagecc = 22.2 − 0.669DFCC + 0.005DFCC^2	0.83	8.7

[a]SLM site number 21 not included.
[b]A natural log transformation was done on the dependent variable mountain big sagebrush cover to compensate for nonconstant variance at the SLM site.
[c]Model abbreviations: Sagecc = mountain big sagebrush canopy cover, DFCC = Douglas fir canopy cover.

is apparent in the high R^2_a values ranging from 0.83 to 0.89 for all models. With only occasional or no Douglas-fir trees, mountain big sagebrush canopy cover is generally >20% on the study areas (Figure 1). Where Douglas-fir canopy cover was ~20%, sagebrush canopy cover dropped to <15% and where Douglas-fir canopy cover was ~35%, sagebrush canopy cover generally decreased to <5% (Figures 1 and 2).

Discussion

Overall regression model

We based the validation model on fewer sites than the full model because we withheld 15 sites for validation (Table 2). We excluded 1 SLM site from both the validation and full model because the regression influential-observation analysis (Neter et al. 1996) indicated that this site had an abnormal influence on the regression relationship. This model derived from data from all 3 study areas for predicting mountain big sagebrush canopy cover was narrowly not validated based upon the percentage of validation observations falling within the prediction intervals (73%), although there was a high correlation value between predicted and observed values (r = 0.91; P < 0.001), indicating a strong linear relationship between predicted and observed values. If only 1 more of the 15 sites withheld to validate this model had been more accurately estimated, the model derived from all 3 sites would have met the pre-set criteria (80%) for validation. The prediction interval width for the overall validation model was similar to that of the models for the individual study areas (~8%). The model accurately predicted observed values of mountain big sagebrush canopy cover that were ≤15% canopy cover but was not as accurate for observed values of >15% canopy cover. We made similar validations at individual study areas with data from the other 2 study areas. The following discussion of models based on individual sites considers the variation encountered in southwestern Montana.

Sugarloaf Mountain

We dropped 1 site from the SLM model for the same reasons it was excluded from the overall model. Canopy covers of Douglas-fir and mountain big sagebrush at this site were 1% and 8.5%, respectively. However, due to a sampling anomaly the

Table 2. Model validation results from over all sites sampled during 1996 and 1997 for predicting mountain big sagebrush canopy cover (%) using Douglas fir canopy cover (%) as the independent variable at sites selected randomly from the 3 southwestern Montana study areas.

Site	Predicted value	80% Prediction interval	Observed value
SLM 4	11.2	7.4–15.1	11.0
SLM 6	11.4	7.5–15.3	11.3
SLM 14	14.8	10.9–18.7	15.3
MLP 1	9.3	5.4–13.2	12.0
MLP 2	17.3	13.4–21.2	11.6+[a]
MLP 4	2.9	0.0[b]–6.8	2.7
MLP 6	2.1	0.0–6.0	0.5
MLP 21	14.2	10.3–18.1	14.9
MLP 22	13.0	9.2–16.9	19.3+
HC 8	8.3	4.4–12.2	10.1
HC 11	9.1	5.3–13.0	10.1
HC 16	3.5	0.0–7.4	2.5
HC 17	9.4	5.5–13.2	10.3
HC 21	14.8	10.9–18.7	19.4+
HC 25	21.4	17.4–25.4	26.1+

[a]Values denoted with + fell outside of prediction intervals.
[b]Negative predicted values and prediction intervals were truncated to 0.

actual Douglas-fir canopy cover of >1%was not obtained by our sample. Because of this and the fact that the normal inference range for this model should be for higher levels of Douglas-fir canopy cover, we omitted the site. The SLM model was not validated for either the MLP or HC study areas based upon the percentage of observations from the MLP and HC study areas falling within the prediction intervals (64% and 60%, respectively). However, correlation values between predicted and observed values were high (MLP, $r = 0.93$; HC, $r = 0.91$; $P < 0.001$). The width of prediction intervals was variable because of the natural log transformation used to compensate for nonconstant variance. The SLM model generally did not predict MLP or HC observed values accurately. However, it did accurately predict the lower values of mountain big sagebrush cover on the HC study area. The SLM model generally under-predicted the value of mountain big sagebrush canopy cover for both the MLP and HC study areas.

Medicine Lodge Peak

Overall, the MLP model for predicting mountain big sagebrush canopy cover was not validated for the SLM study area, but it was validated for the HC study area based upon the percentage of observations from the SLM and HC study areas falling within the prediction intervals (68% and 84%, respectively). The HC study area also had a higher correlation between predicted and observed values than did the SLM study area (SLM, $r = 0.84$; HC, $r = 0.93$; $P < 0.001$). The width of the prediction interval was ~7%. The MLP model often did not predict SLM or HC observed values with high accuracy. The MLP model generally over predicted mountain big sagebrush canopy cover for the SLM study area and under predicted it for the HC study area.

Hells Canyon

Overall, the HC model for predicting mountain big sagebrush canopy cover was not validated for the SLM study area but was validated for the MLP study area based upon the percentage of observations from the SLM and MLP study areas falling within the prediction intervals (64% and 84%, respectively). The MLP study area also had a higher correlation between predicted and observed values (SLM, $r = 0.84$; MLP, $r = 0.95$; $P < 0.001$). The width of the prediction interval was 7.5%. The HC model often did not predict SLM or MLP observed values accurately. The HC model over-predicted mountain big sagebrush canopy cover for the SLM study area almost without exception, and generally under-predicted mountain big sagebrush canopy cover for the MLP study area. However, the HC

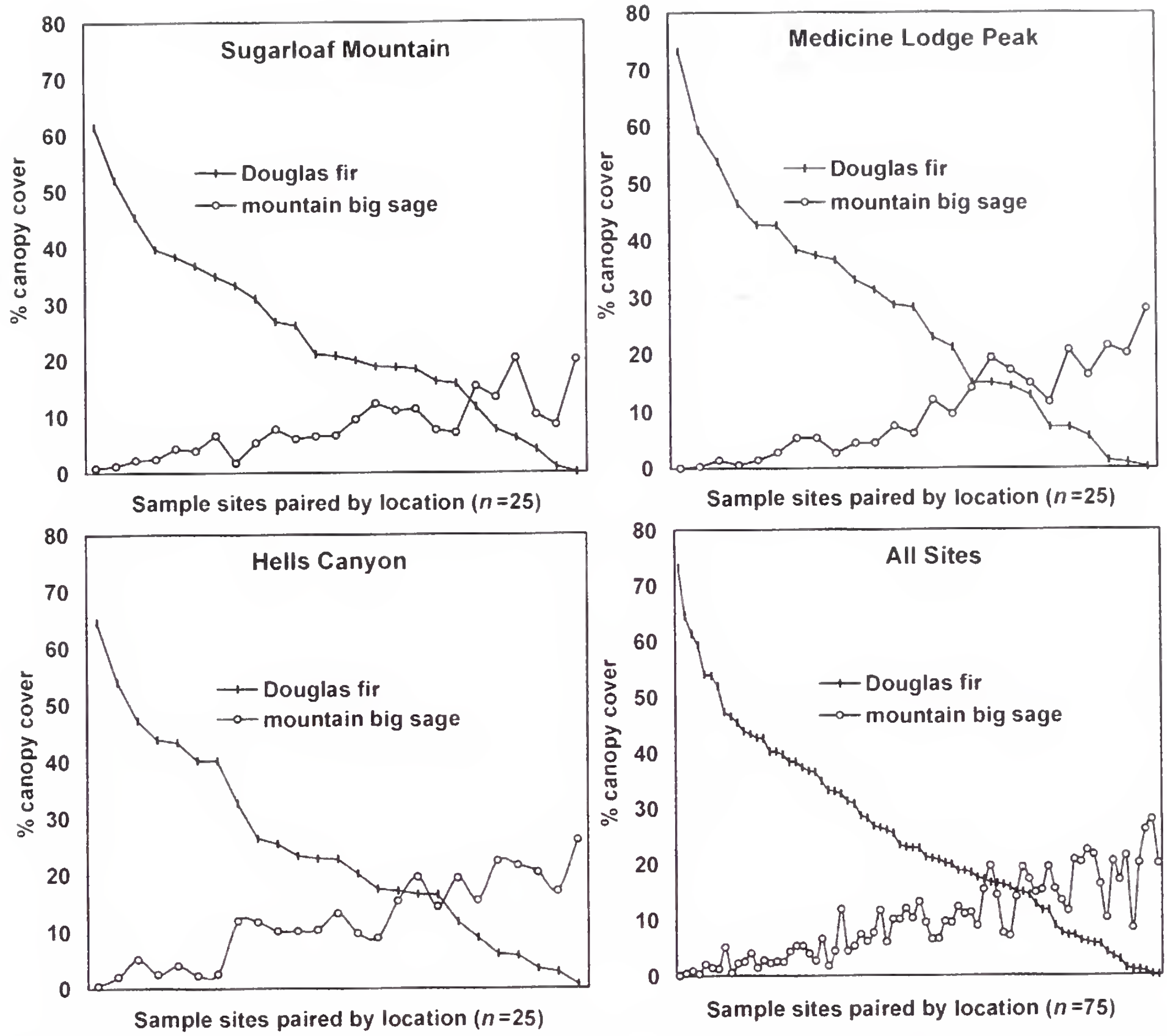


Figure 1. Average Douglas-fir and mountain big sagebrush canopy cover values (%) paired as measured during 1996 and 1997 at each of the 3 southwestern Montana study sites (n = 25) and combined over all sites (n = 75).

model was considerably better at predicting the observed values at MLP compared to SLM.

Management implications and conclusions

Our findings of Douglas-fir's negative relationship to mountain big sagebrush canopy cover supports the opinion of Gruell et al. (1986) who stated that the big sagebrush in southwestern Montana was declining due to competition from Douglas-fir. In southwestern Montana as Douglas-fir increases to >20% and >35%, mountain big sagebrush cover declines from >20% to <15% and <5%, respectively. The negative relationship of Douglas-fir establishment to mountain big sagebrush canopy cover has several management implications.

What level of Douglas-fir canopy cover is acceptable depends on overall management goals, including vegetation and wildlife species desired. Optimum habitat for ungulates will depend on ratios of security and thermal cover to foraging areas in the habitat (Thomas 1979). Therefore, for ungulates and perhaps other fauna, it is likely that increasing Douglas-fir cover will benefit their use of habitat patches by providing more and better security and thermal cover through time. However, it also is likely that increasing Douglas-fir cover will eventually retard production of forage species, such as mountain big sagebrush.

Loss of sagebrush will negatively impact some fauna, especially sagebrush obligates, at lower levels of Douglas-fir establishment. These animals include many species that derive both their cover and forage requirements from sagebrush or associated plants that all decrease under Douglas-fir cover. Welch (2005) found 62 studies that considered impacts of big sagebrush loss on 28 different small mammals (excluding the obligate pygmy rabbit [*Sylvilagus idahoensis*]). Only 4 species of these

Figure 2. A common vegetative pattern found at the study sites in southwestern Montana during 1996 and 1997 with older, denser stands of Douglas-fir upslope expanding into mountain big sagebrush-dominated communities on the lower slopes and bottoms (top). Conditions under a Douglas-fir canopy cover >35% often preclude mountain big sagebrush and associated species (middle). With low amounts of Douglas-fir, conditions often are optimal for ungulates and certain other wildlife with a good balance of forage with security and thermal cover, although some animals including sagebrush obligates like sage-grouse may decline as any Douglas-fir canopy establishes (bottom).

small mammals had no reported negative impacts from sagebrush loss. These small mammals are among the 90 mammals that Welch (2005) described as having a facultative relationship with big sagebrush, meaning they associate with big sagebrush between $\simeq$20-80% of the time. Also listed are 89 bird species with a facultative association with big sagebrush. Animals that are known obligates to big sagebrush increase the total mammals and birds by 2 and 4 species, respectively. Thus, at least 92 mammals species and 93 bird species will be impacted to varying degrees by changes in big sagebrush cover. Recently, much attention has been devoted to the welfare of sage-grouse due to the bird's obligatory habit with often manipulated sagebrush rangelands (Connelly et al. 2000, Wambolt et al. 2002). The level of sagebrush cover acceptable for wildlife species varies considerably. Clearly, many wildlife species thrive with some level of sagebrush cover in their habitats. Our findings should enhance understanding of the implications of management alternatives where conifers and sagebrush are juxtaposed.

Our findings provide a basis to evaluate trade-offs in wildlife cover and forage opportunities relative to tree cover in these communities. Any tree control program should consider that Douglas-fir canopy cover rarely is uniform at a landscape level but rather occurs in patches of different cover levels. Although prescribed fire is one option for controlling encroaching Douglas-fir, burning may have long-term negative impacts on mountain big sagebrush, that reduce habitat and forage values for ungulates (Harniss and Murray 1973, Wambolt et al. 2001). This could be especially detrimental on winter ranges for many animals, including ungulates, as sagebrush taxa are especially important forage during winter (Wambolt 1996, Connelly et al. 2000). Although our models likely are not appropriate, the concepts studied and discussed in this paper are relevant in other conifer types throughout the western states.

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Effect of method, site, and taxon on line-intercept estimates of sagebrush cover

Carl L. Wambolt, Michael R. Frisina, Stephen J. Knapp, and R. Margaret Frisina

Abstract: Sage-grouse (*Centrocercus* spp.) are arguably the best known of the many wildlife species that inhabit sagebrush (*Artemisia*) ecosystems. Lack of standardization in the procedures used to assess sagebrush cover may contribute to inconsistencies in reported habitat requirements for sage-grouse and other wildlife. We compared 3 applications of the line intercept method for 3 sagebrush taxa. We sampled 2 mountain big sagebrush (*Artemisia tridentata vaseyana*) sites, 2 Wyoming big sagebrush (*A. t. wyomingensis*) sites, and 1 black sagebrush (*A. nova*) site to determine if the results generated by the 3 methods differed. Percent cover as determined by methods commonly used by agencies was up to 2.6 times greater than that from research applications. Cover differences among techniques were influenced by taxa and site ($P \leq 0.001$) as both affected shrub morphology. We believe it will be difficult to identify and achieve wildlife habitat guidelines for minimal sagebrush cover requirements if methodologies are not standardized.

Key words: *Artemisia tridentata vaseyana*, *Artemisia tridentata wyomingensis*, *Artemisia nova*, big sagebrush, black sagebrush, *Centrocercus* spp., cover, line-intercept, sage-grouse, vegetation

The availability of methodology to accurately estimate cover in a consistent manner would benefit wildlife management. Cover is indicative of ecological dominance and the most important variable in predicting forage production of shrubs like sagebrush (*Artemisia*) (Wambolt et al. 1994). Since Canfield (1941) first described the use of the line intercept technique for sampling vegetation cover, variations of the technique have been widely applied in many vegetation types. This technique measures the portions of plants that are intercepted by a line transect positioned directly above all foliage, thereby obtaining an estimate of cover for the plants. Perhaps the greatest application of line intercept has been for sampling cover of low to medium height (<1m) shrubs. When used for shrubs, any portion intercepted from ground level to the top of the foliage is recorded as cover.

Variations of Canfield's (1941) technique have been especially important in recent years for assessing the cover of shrubs in sagebrush habitat types. Many wildlife species require adequate sagebrush cover to meet their security, thermal, and forage needs (Welch 2005). Accurate determination of cover has become particularly paramount for management of sage-grouse (*Centrocercus* spp.) in diverse sagebrush habitats given recent petitions to place the bird on the threatened and endangered species list (Connelly et al. 2004).

Because differences in sagebrush cover types and taxa may be ecologically significant for sage-grouse (Connelly et al. 2000) and numerous other wildlife species (Welch 2005), the variation in results obtained by different methodology may create problems if the cover values obtained during research are subsequently adapted for management recommendations. We believe at present awareness of the potential variation from application of different line intercept methods is lacking (United States Forest Service 1993, Bureau of Land Management 1996, Connelly et al. 2003).

Our objective was to determine if 3 common methods of using the line intercept technique may alter the results of cover determination within 5 sagebrush communities and 3 sagebrush taxa. We also wanted to determine if morphological differences dependent upon taxa and site environmental characteristics would affect community intercept values among the 3 methods.

Study areas

Sagebrush taxa were the only woody plants at the 5 sites sampled with >trace amounts of cover. Each site was dominated by only one of the following taxa: mountain big sagebrush (*Artemisia tridentata vaseyana*), Wyoming big sagebrush (*A. t. wyomingensis*), or black sagebrush (*A. nova.*) (Figure 1). The Barry's Landing black sagebrush site (lat 45.14482 N, long 108.22330W; elev 1390 m) and Red Buttes Wyoming big sagebrush site (lat 44.99852N, long 108.30237W; elev 1240 m) were located on the southeast flank of the Pryor Mountains near the Montana-Wyoming border approximately 45 and 30 km, respectively, north of Lovell, Wyoming. The Trail Creek Wyoming big sagebrush site (lat

Figure 1. Morphological differences are evident among the 3 sagebrush taxa sampled at: Barry's Landing (A-black sagebrush), Red Buttes (B-Wlyoming big sagebrush), Trail Creek (C-Wyoming big sagebrush), Casey Lake (D-mountain big sagebrush), and Sheepeater Cliffs (E-mountain big sagebrush). A plumb bob is vertically projected to determine intercept on a small Wyoming big sagebrush plant along a transect line held high enough to clear the crowns of taller plants (F). This illustrates the value of a plumb bob to accurately determine intercept for a variety of shrub size and form classes as some plants and plant parts may be a considerable distance from the transect line making accurate estimates of intercept without a plumb bob difficult.

45.05613N, long 110.73212W; elev 1990 m) and Casey Lake mountain big sagebrush site (lat 45.06978N, long 110.66936W; elev 2210 m) were located approximately 5 km and 12 km east of Gardiner, Montana, respectively. The Sheepeater Cliffs mountain big sagebrush site (lat 44.88783N, long 110.73343W; elev 2231 m) was located 30 km south of Gardiner in Yellowstone National Park (USDI–NPS). All sites supported sagebrush stands with adequate cover (Table 1) to represent sagebrush habitat types typical of the western states as described by Welch (2005). Average sagebrush heights were as follows: Red Buttes–2 height (age) classes of 20 and 50 cm were equally present on this site; Barry's Landing–20 cm; Trail Creek–60 cm; Casey Lake–1 m; Sheepeater Cliffs–70 cm.

Methods

We established 10 random 30-m line transects at each sampling site, a sample size previously proven adequate to determine cover in sagebrush communities (Wambolt and Sherwood 1999). We used the same 10 lines to obtain cover (intercept) data by all 3 methods to compare results. Sampling was conducted during summer 2003 and all measurements using the 3 methods on a given line were made within 1 hour.

Table 1. Sagebrush cover (%) transect (n = 10) means and standard error of the mean by site for 3 line intercept methods compared at 5 study sites in Montana and Wyoming, summer 2003.

Site	Taxon	Method[a]	Mean cover	SEM
Barry's Landing	Black sagebrush	1	9.4A[b]	
		2	11.8AB	
		3	13.2B	
				1.0
Red Buttes	Wyoming big sagebrush	1	20.0A	
		2	27.4B	
		3	25.8B	
				1.0
Trail Creek	Wyoming big sagebrush	1	10.7A	
		2	18.8B	
		3	18.4B	
				0.5
Casey Lake	Mountain big sagebrush	1	23.4A	
		2	40.4C	
		3A	36.0B	
		3B	44.1D	
				1.2
Sheepeater Cliffs	Mountain big sagebrush	1	13.0A	
		2	28.0B	
		3A	31.1BC	
		3B	34.1C	
				1.6

[a]Methods 1, 2, and 3 are detailed in the methods section; 3A and 3B designate data obtained by 2 individuals following the procedures of method 3 at 2 study sites.
[b]Means among methods differ ($P \leq 0.05$) within sites when followed by a different letter.

Method 1 recorded sagebrush intercept in 3 cm units (Wambolt and Payne 1986, Connolly et al. 2003). Openings in live foliage ≥3 cm were recorded as non-sagebrush intercepts. Thus, we excluded both open spaces and dead portions of the plant. Although not included as cover, the intercept of the standing dead portion of sagebrush plants was recorded separately to provide insight into possible differences with other methods. All measurements made using method 1 were obtained by vertically projecting a plumb bob from the transect line to plants to determine what intercepts were directly beneath the line.

Method 2 consisted of estimating cover using intercepts of sagebrush plant perimeters by measuring from first to last live foliage, while ignoring openings or dead material within the perimeter of each shrub's live foliage (United States Forest Service 1993, Bureau of Land Management 1996). Again, the measurements were taken with a plumb bob to precisely determine intercept beneath the lines.

Method 3 was similar to method 2 in recording the intercept values based on plant perimeters without regard for openings or dead material (United States Forest Service 1993, Bureau of Land Management 1996). However, we did not employ a plumb bob with method 3 and intercept was an ocular estimate of foliage beneath the transect lines.

We used different observers for each method at all sites. This procedure avoided any carry-over influence that could have resulted from the same observer recording intercept multiple times on the same line. At the 2 mountain big sagebrush sites, method 3 was recorded by 2 observers. We reasoned that because this method did not use a plumb bob, it would have a greater probability to vary among observers.

We also tested for the possibility that the amount of dead foliage might explain differences between method 1 and the other methods. To do this we combined the live cover obtained by method 1 with the percent of cover intercepted that was dead using method 1 procedures and compared that

total to both method 2 and the live cover from method 1.

We conducted a two-way ANOVA with site and method as the factors with transects blocked after insuring the data were normally distributed. A two-way ANOVA with taxon and method as the factors was also conducted to test if taxon had a similar relationship to method as found with site. The Bonferroni *t* procedure protected by a prior F test was used for comparing treatment means. SAS Version 9 was used for all statistical analyses (SAS Institute Inc. 2002). All differences considered significant are at $P \leq 0.05$.

Results

Site and taxon both interacted with method ($P \leq 0.001$). Percent cover differed in 15 of 21 comparisons between methods (Table 1). Our 2 mountain big sagebrush sites had the greatest variation among methods and the black sagebrush site the least. The 5 sites and 3 taxa provided a range of cover values from 9.4% at Barry's Landing in black sagebrush by method 1 to 44.1% at Casey Lake in mountain big sagebrush by method 3. Method 1 yielded the lowest cover values at all sites. Method 1 was different from other methods in 11 of 12 comparisons (Table 1). The only exception was the comparison between methods 1 and 2 with black sagebrush. Percent cover for methods 2 and 3 differed in 3 of 7 comparisons. One of our 2 comparisons of different observers using method 3 differed. Percent cover determined varied considerably by taxon and site ranging from 2.1% between methods 2 and 3 at Trail Creek with Wyoming big sagebrush to 162.3% between methods 1 and 3 at Sheepeater Cliffs with mountain big sagebrush.

We learned that inclusion of dead cover with method 1 was different when compared to only live cover at 4 of the 5 sites, with the exception being Sheepeater Cliffs with mountain big sagebrush (Table 2). Our comparisons between the sum of live and dead cover from method 1 with method 2 differed at all sites except Barry's Landing for black sagebrush. At the 4 sites with either Wyoming big sagebrush or mountain big sagebrush the addition of dead foliage cover to method 1 resulted in differences between methods 1 and 2.

Discussion

We found that method 1, commonly followed in research applications (Wambolt and Payne 1986, Connolly et al. 2003), yielded lower cover values for shrubs than variations of our methods 2 and 3 adapted by agencies like the Bureau of Land Management and United States Forest Service (Floyd and Anderson 1987, United States Forest Service 1993, Bureau of Land Management 1996). Methods 1 and 2 were very objective and repeatable by different observers with a high level of consistency. However, when observers do not use a plumb bob as with method 3, intercept decisions may become more subjective and greater variation among observers should be expected. Although our data addressing this point are limited, we believe this likely occurred in our study because the variability between method 3 and the other methods resulted in a wider range of cover values than obtained by method 2.

The variation obtained for sagebrush cover among the 3 methods is at least partially derived from ecological differences inherent to the 5 study sites and ultimately the 3 taxa adapted to their environments. Site and taxa differences are expressed as variation in shrub morphologies. Therefore, the interactions between both site and taxon with method are logical as taxon changes with site environmental conditions and both relate to well established morphological differences among taxa (Wambolt el al. 1994).

Taxon which is site dependant serves well as a proxy variable for morphological variation (Wambolt et al. 1994). Such differences in shrub morphology account for considerable variation of cover within and among our taxa (Figure 1). Because heights of individual shrubs were not sampled we could not test the effect of sagebrush height on cover. However, this characteristic appears directly related to the amount of variation that should be expected among the methods. Plant height varies with different combinations of taxon, age, environment (sites), and browsing history. We learned that communities with tall plants will generally have interspersed short plants for which an accurate determination of intercept is relatively difficult, especially when not using a plumb bob. However, intercept estimates of short plants without any tall plants interspersed among them are generally easier to determine than for tall plants alone. This is true because lower placement of transect lines when sampling shorter plants allows field observers using method 3, without the aid of a plumb bob, to view shrub intercepts from a closer to vertical position with little distance between the transect line and foliage, thereby likely increasing accuracy (Figure 1-F). A greater consistency among our methods at sites with shorter plants is evident as a comparison of our data for the shortest and tallest taxa, black sagebrush and mountain big sagebrush, respectively, illustrate this point (Table 1).

Table 2. Sagebrush cover (%) transect (n = 10) means and standard error of the mean by site for line intercept methods 1 and 2 compared to cover obtained by method 1 with cover of dead foliage included at 5 study sites in Montana and Wyoming, summer 2003.

Site	Taxon SEM	Method[a]	Mean cover	
Barry's Landing	Black sagebrush	1	9.4A[b]	
		1 (with dead)	12.2B	
		2	11.8AB	
				0.7
Red Buttes	Wyoming big sagebrush	1	20.0A	
		1 (with dead)	23.8B	
		2	27.4C	
				0.8
Trail Creek	Wyoming big sagebrush	1	10.7A	
		1 (with dead)	13.7B	
		2	18.8C	
				0.5
Casey Lake	Mountain big sagebrush	1	23.4A	
		1 (with dead)	28.9B	
		2	40.4C	
				0.9
Sheepeater Cliffs	Mountain big sagebrush	1	13.0A	
		1 (with dead)	16.0A	
		2	28.0B	
				1.3

[a]Methods 1, 2, and 1 with dead are detailed in the methods section.
[b]Means among methods differ ($P \leq 0.05$) within sites when followed by a different letter.

Shrub compactness also influences variation among the 3 methods (Hormay 1949). In addition to being taller, mountain big sagebrush is often less compact in form than the other 2 taxa (Wambolt et al. 1994). Due to relatively more open foliage, in the mountain big sagebrush stands there were more openings ≥3 cm that resulted in greater differences between method 1 and the other methods. The open nature of mountain big sagebrush is accentuated on sites with heavy snow cover. These environments, usually at relatively higher elevations, were best represented in our study by the Sheepeater Cliffs site. We believe the differences between method 1 and the other methods were greatest at Sheepeater Cliffs due to the relatively open foliage of mountain big sagebrush (Hormay 1949). The open foliage trait apparently created more disparity among sampling methods than the fact that mountain big sagebrush plants were ~30 cm taller at Casey Lake. Black sagebrush had the densest foliage with relatively few gaps ≥3 cm. This is consistent with black sagebrush having the least variation between method 1 and other methods. Moderate to heavy browsing of these sagebrush taxa also results in denser compact foliage (Wambolt et al.1994, Wambolt 1996) and may lead to less variation among cover sampling methods.

We believe the amount of dead foliage might partially explain why method 1 varied considerably from the other methods. Our data suggest that although dead foliage contributes to inflated cover values for methods 2 and 3 (Table 2), that it was not the most important factor. The open nature of many sagebrush plants with numerous foliage openings ≥3 cm, as discussed above, may often be a more important determinant of intercept values obtained by the different methods. Some sagebrush stands will contain more dead cover than did our 5 study sites. We believe that under that circumstance dead foliage would have a greater influence on differences among our methods. Sagebrush stands require several decades to reestablish after disturbance (Wambolt and Payne 1986). During that interval the portion of dead foliage would generally be less than at our sites and thereby less likely to create additional variation between our method 1 and methods 2 and 3.

Conclusions

No previous research has quantified cover differences obtained by the popular variations of Canfield's (1941) technique that we tested. Our results show that currently the intercept technique is used with considerable variation in procedure, often making monitoring of management objectives based on research methodology unreliable. Considerable differences should be expected between cover values obtained for sagebrush taxa by the methods studied. These differences may be especially critical for sagebrush dependent species like sage-grouse for which established sagebrush cover requirements are known (Connelly et al. 2000). Goodrich and Huber (2001) cautioned that problems might result when resource managers attempt to apply research based recommendations and concluded USDA Forest Service (1993) procedures for line intercept that specify including openings in shrub crowns overestimate cover.

Many important wildlife species including sage-grouse are impacted in habitats with inadequate sagebrush cover (Connelly et al. 2000, Wambolt et al. 2002). To evaluate habitats for sagebrush cover our findings suggest that whenever line intercept results are presented that the authors be explicit about their method. We believe the approach employed with our method 1 where a plumb bob accurately determined intercept and foliage openings >3 cm were not included would be a logical standard in the future to determine sagebrush cover for most purposes.

Although Connelly et al. (2003) did not have comparative data among methods, they agree with us in their recommendation of procedures similar to our method 1. This approach has been used successfully for research as it is the most sensitive to change over time and the ecological influence of sagebrush cover on communities (Wambolt and Payne 1986). Perhaps different approaches may suffice for other purposes. We believe resource managers should consider our findings as they attempt to relate their areas to management suggestions based on research for species like the sage-grouse (Connelly et al. 2000). Welch (2005) reported that inadequate sagebrush cover levels may negatively impact at least 93 bird and 92 mammal species. We argue that a standardized consistent method that does not overestimate sagebrush cover be adapted for the benefit of these wildlife species.

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Notes

Mule deer and elk winter diet as an indicator of habitat competition

Michael R. Frisina, Carl L. Wambolt, W. Wyatt Fraas and Glen E. Guenther

ABSTRACT

Mule deer populations have gradually declined in recent decades, while elk have often increased throughout their common ranges. The cause is uncertain and a source of debate. Increasing elk numbers on these ungulates winter ranges may be causing competition for resources. We contrast winter diets of mule deer and elk and relate them to population trends of both species on the Mount Haggin Wildlife Management Area in southwest Montana. From 1978 through 1996 elk populations increased and began to decline in 1997. Mule deer increased from 1978 through 1989, but declined from 1990 through 1997. The same five browse species comprised 95% and 52% of the mule deer and elk winter diets respectively. These data indicate there is a potential for competition between mule deer and elk sharing winter ranges. Because elk have a more varied diet (55% browse, 32% grass, 12% forbs) than mule deer (98% browse, 2% grass, 0.5% forbs) on this winter range, it is likely mule deer will be the most negatively impacted.

INTRODUCTION

During the past several decades elk (*Cervus elaphus*) populations have increased across the western United States (Peek et al. 1982, O'Gara and Dundas 2002). Concurrently concern has been expressed that mule deer (*Odocoileus hemionus*) populations are on a gradual, but steady decline (Wallmo 1978, Connolly 1981). Much conjecture has been put forth regarding the causes of the mule deer decline; there are probably many factors involved. Our objective was to determine mule deer and elk winter diets and consider the possibility that overlapping diets might impact one or both ungulates.

STUDY AREA

The study area within the Mount Haggin Wildlife Management Area (MHWMA) is approximately 16 km southeast of Anaconda in southwest Montana and was described in detail by Guenther (1989). The MHWMA was purchased in 1976 by the Montana Department of Fish, Wildlife and Parks (MFWP) to conserve habitat for a variety of wildlife species including elk and mule deer. All 18 sampling locations studied were on ungulate winter range within the northern portion of the MHWMA (Guenther 1989).

The topography is characterized by mountainous slopes. Sampling sites are located near the Continental Divide at elevations between 1577 m and 1943 m. Average annual precipitation is about 340 mm, with 47% falling from April through July. June and February are the wettest and driest months averaging 70 and 16 mm of precipitation, respectively.

Although vegetation on the study area is diverse, the bitterbrush (*Purshia tridentata*) – grass type predominates (Guenther 1989). Many of the study sites show the impacts of historic intensive livestock grazing and air born pollutants from the nearby Anaconda smelter. Guenther (1989) identified 12 shrub, 25 graminoid, and 44 forb species, respectively that occur on the 18 sampling locations. Other common shrubs in the area include snowberry (*Symphoricarpos albus*) and Oregon grape (*Berberis repens*). The most common grasses are Kentucky bluegrass (*Poa pratensis*), basin wildrye (*Elymus cinerus*), needleandthread (*Stipa comata*), green needlegrass (*S. viridula*), rough fescue (*Festuca scabrella*), Idaho fescue (*F. idahoensis*), and bluebunch wheatgrass (*Agropyron spicatum*). Among the most abundant forbs are the exotic whitetop (*Cardaria draba*) and spotted knapweed which have invaded nine of the study sites. Native long-leaved aster (*Aster chilensis*) is also common. Rocky Mountain juniper (*Juniperus scopulorum*) and lodgepole pine (*Pinus contorta*) is present and Douglas-fir (*Pseudotsuga menziesii*) appears to be increasing on some sites (Guenther 1989). Small stands of aspen (*Populus tremuloides*) are scattered across the winter range.

The MHWMA provides year-long range for elk, mule deer, moose (*Alces alces*), white-tailed deer (*Odocoileus virginianus*), and pronghorn (*Antilocapra americana*) (Frisina 1982, Frisina 1992). The portion of the MHWMA studied is an important winter range for elk, mule deer, and moose.

METHODS

Mule deer and elk feces were analyzed for winter diet during 1991 from 18 and 13 sampling sites, respectively. The samples were sent to the

Composition Analysis Laboratory at Colorado State University for diet determination using microhistological techniques (Sparks and Malechek 1968). Each sample was a composite from 10 pellet groups. From each composite sample, the mean composition of plants in the diet was determined from five slides of 20 fields each.

Mule deer and elk population trends were determined from aerial surveys flown during winter when clear skies, cold temperatures, and snow cover provided ideal conditions for observing animals. During the years of our study, 1978 through 1997, the entire winter range was flown each winter to obtain trend counts. The first author was the observer on all flights. Separate flights were made for deer and elk. A mule deer trend count was obtained every winter and an elk trend count was completed for 16 of the 20 winters. During four years weather conditions were unusually mild and elk too widely scattered for a comparable survey to be accomplished. When weather conditions are unusually mild not all elk migrate to the winter range. A fixed-wing aircraft was used for all elk counts. A small helicopter was used to conduct nine of the mule deer counts (1978 through 1984, and 1997) and a fixed wing aircraft for 11 of the counts (1986 through 1996). The open nature of the winter range (lack of dense forest) made deer similarly observable from both types of aircraft. Sex and age are not relevant to our study. To minimize observation bias resulting from the 2 types of aircraft we used the actual number of animals observed without separation by sex or age for monitoring population trend (Fig. 1).

RESULTS

Mule Deer Diet

Twenty-five taxa or plant groups were identified in the winter diet of mule deer (Table 1). These consisted of 14, 5, and 6 browse, grass, and forb taxa, respectively. Browse was the most important component with five species comprising 95% of the diet: antelope bitterbrush, Oregon grape, Rocky Mountain juniper, Douglas-fir, and, lodgepole pine. Antelope bitterbrush provided over half of the mule deer winter diet (Table 1). *Purshia* is very important to the nutrition of mule deer (Young and Clements 2002). In a synthesis of mule deer food habits studies for the Western United States and Canada, Kufeld et al. (1973) rated antelope bitterbrush as a heavily used browse during winter. Kufeld et al. (1973) considered Rocky Mountain juniper, Oregon grape, and Douglas fir to be of moderate value, and lodgepole pine of low value. Grasses and forbs combined contributed only about 2% to the winter diet of mule deer (Fig. 2). Idaho fescue and rough fescue combined were the only herbs ≥1% of the winter diet. Idaho fescue was considered of moderate winter value to mule deer and rough fescue of low winter value by Kufeld et al. (1973).

Elk Diet

Twenty-four plant species were identified in the winter diet of elk (Table 1). These consisted of 9, 10, and 5 browse, grass, and forb taxa, respectively. Browse was the most significant portion at 55% of the diet. Only three browse species, antelope bitterbrush, Oregon grape, and Douglas-fir comprised 53% of the diet. Kufeld (1973) considered antelope bitterbrush a highly valuable winter forage plant, Oregon grape a valuable plant, and Douglas-fir to be of low value to wintering elk. Grasses and forbs combined comprised about 44% of elk winter diets. Grasses contributed 32% with fescues the most important at 17%. Previous studies found both rough fescue and Idaho fescue to be highly valuable winter forage for elk (Kufeld 1973). Forbs were least eaten by elk during winter at 12% of the diet, but lupine did comprise 9% of the diet. The only documented species of lupine at the study sites was *Lupinus wyethii*. Kufeld (1973) considered lupines of moderate value to wintering elk.

CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

The winter diets of mule deer and elk were similar with five browse plants (antelope bitterbrush, Oregon grape, Rocky Mountain juniper, Douglas-fir, and lodgepole pine) comprising 95% of the deer diet and 55% of the elk diet (Table1). However, the elk diet was more diverse than deer with grasses and forbs contributing 32% and 12% to the diet respectively. While 98% of the deer diet was browse, this forage class contributed 56% to that of elk.

Population trend data indicate elk increased from an observed number of 172 in 1978 to 700 in 1996 and began to decline in 1997 (Fig. 1). Likewise, mule deer increased from 202 in 1978 to 586 in 1989, but declined between 1990 and 1997 (Fig. 1).

Guenther et al. (1993) found utilization on MHWMA bitterbrush ranged from 57% to 96%, averaging 80% at 18 sampling sites during the winter of 1998-1989. They noted that the majority of bitterbrush plants appeared hedged due to heavy historical browsing. Fraas (1992) found lower browsing rates at the same sites during the winter of 1990-1991 (0 to 60%). Fraas (1992) attributed the difference in browsing rate to differences in sampling methods. While Guenther (1989) chose twigs on the outermost portion of each plant, Fraas (1992) ran-

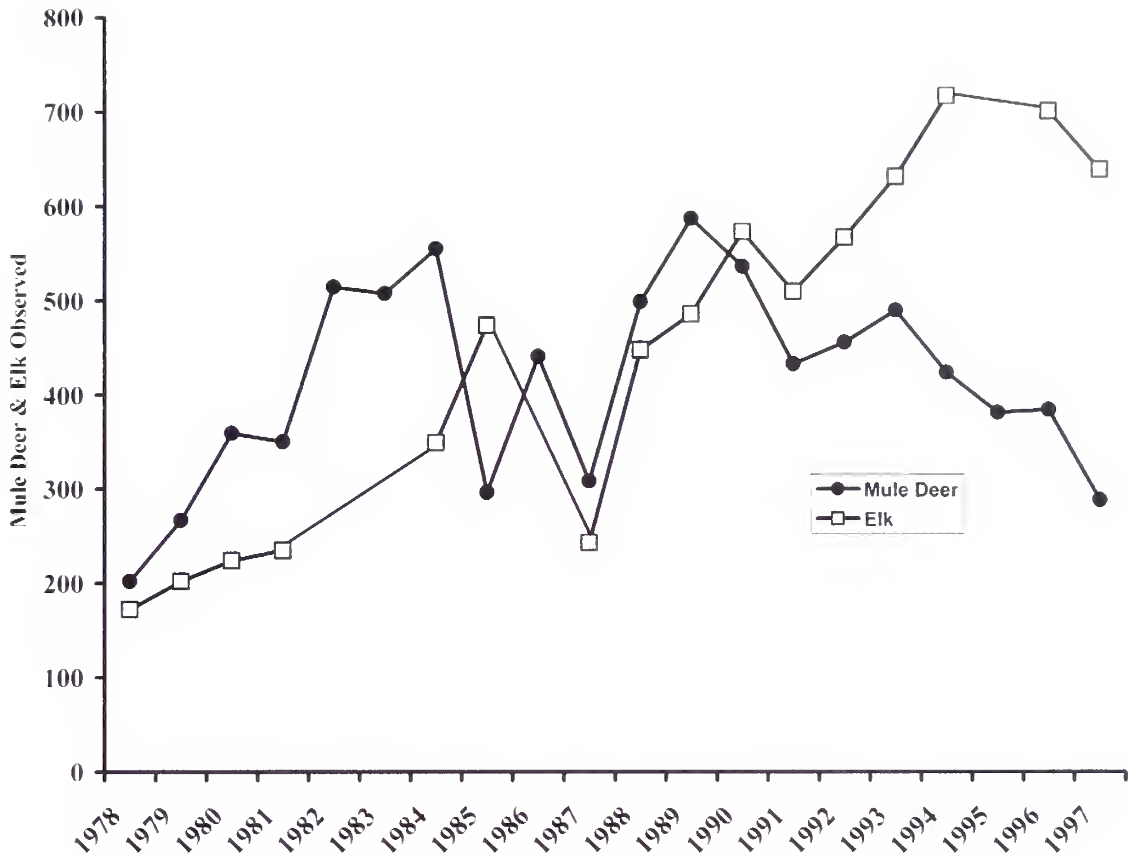

Fig 1. Population trend for mule deer and elk wintering on the Mount Haggin WMA, 1978-1997.

domly chose branches, some deep within the canopy and thus not as susceptible to browsing. The diet similarity between elk and mule deer indicates the potential for competition between these species. The decline in mule deer trend between 1990 and 1996 with a concomitant upward trend of elk through 1996 indicates competition may be occurring. Elk diets at MHWMA are more varied providing them a survival advantage over mule deer when difficult winter conditions occur. Douglas-fir and lodgepole pine are both considered a low value browse for elk and deer (Kufeld 1973, Kufeld et al. 1973), yet contributed 8% and 3%, respectively, to the diet. This relatively high contribution of low value browse to the winter diets is a further indication that the combined populations of mule deer and elk may be exceeding habitat carrying capacity. Guenther et al. (1993) found browsing to be intense enough to suggest a management strategy directed toward reducing the number of wintering deer. Our data indicate it maybe more important to control the size of the wintering elk population.

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Table 1. Mean percent plant content in feces found within the 18 and 15 sampling sites for mule deer and elk, respectively, on the Mount Haggin Wildlife Management Area, 1991 (T = species cover <0.1%).

Species		Mule Deer	Elk
Grasses		**2.0**	**31.9**
Wheatgrasses	[illegible] spp	0.1	[illegible]
Bentgrasses	[illegible] spp		0.2
Brome grasses	[illegible] spp	0.1	[illegible]
Sedges	[illegible] spp	[illegible]	[illegible]
Fescue grasses	[illegible] spp	1.1	17.4
Rushes	[illegible] spp	-	0.3
Bluegrasses	[illegible] spp	0.6	[illegible]
Needlegrasses	[illegible] spp		[illegible]
Junegrass	[illegible]	-	0.4
Unknown grasses			0.1
Forbs		**0.5**	**12.0**
Pussytoes	[illegible]	T	
Sunflower family	[illegible] spp	0.1	[illegible]
Milkvetch & Locoweeds	[illegible] spp		[illegible]
Arrowleaf balsamroot	[illegible]	0.1	
Common horsetail	[illegible]		[illegible]
Wyeth lupine	[illegible]	[illegible]	[illegible]
Phloxes	[illegible] spp	T	T
Flannelleaf mullein	[illegible]	T	
Shrubs/Trees		**97.4**	**55.3**
Kinnikinnick	[illegible]	T	
Serviceberry	[illegible]	0.1	
Fringed sagewort	[illegible]	1.1	
Oregon grape	[illegible]	22.4	10.9
Winterfat	[illegible]		1
Rubber rabbitbrush	[illegible]	1.6	0.1
Green rabbitbrush	[illegible]	1.1	-
Rocky Mountain juniper	[illegible]	17.0	[illegible]
Douglas fir	[illegible]	[illegible]	[illegible]
Antelope bitterbrush	[illegible]	[illegible]	34.4
Lodgepole pine	[illegible]	[illegible]	[illegible]
Quaking aspen	[illegible]		0.1
Raspberry	[illegible] spp	T	
Russet buffaloberry	[illegible]	[illegible]	[illegible]
Common snowberry	[illegible]	0.1	
Gray horsebrush	[illegible]	1.2	

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Ground-truthing the "Sagebrush Land Cover-Montana" Gap Analysis Map: A Summary of Progress

Michael R. Frisina and Carl L. Wambolt

The Montana Gap Analysis Project was initiated in 1991. Among it's purposes was the identification of Montana vegetation types (Redmond et al. 1998). Montana's land cover was mapped by a 2-stage digital classification procedure applied independently to 33 Landsat Thematic Mapper images covering the state (Redmond et al 1998). Shrublands were classified into 7 cover types, among them were maps of silver sagebrush and sagebrush distribution.

From the Gap Analysis data, the Montana Fish, Wildlife & Parks (MFWP) Information Services Unit produced a map of "Sagebrush Land Cover-Montana". The map combines the distribution of several sagebrush taxa and land types—big sagebrush steppe, mountain big sagebrush, Wyoming big sagebrush, basin big sagebrush, black sagebrush steppe, and juniper/sagebrush/grass—into a single layer depicting the overall distribution of sagebrush. MFWP has used this map as a basis for planning and management of sage-grouse and other fauna closely tied to sagebrush habitats.

We are among those who have expressed concerns regarding the accuracy of the "Sagebrush Land Cover-Montana" map. We have found that for some areas in which we are familiar the map does not seem to accurately depict the distribution of sagebrush. Whether this is a widespread problem or isolated to a few areas is unknown. Therefore in 2004 we began an effort to test the accuracy of the "Sagebrush Land Cover-Montana" map by selecting 3 study areas in which we intend to compare what the map indicates as sagebrush distribution with what actually occurs. Study sites in the Pryor Mountains, Flathead Indian Reservation near Hot Springs, MT, and Ruby-Gravelly-Snowcrest areas south of Dillon, MT were selected.

In 2004, 51 sites on the Flathead Indian Reservation and 34 in the Pryor Mountains were visited. At each site, location was recorded using GPS technology and notes were made on the presence or absence of sagebrush. If any shrub other than sagebrush was present it was noted. Our data will be compared with what the "Sagebrush Land Cover-Montana" map indicates as present. During fall 2005 additional sites will be visited in the Pryor Mountains. During 2006 sites will be visited in the study area south of Dillon, MT. Once data is collected for all 3 study areas a comparison will be made of what the map shows as distribution versus what we found to actually occur. Redmond et al. (1998) emphasized that any decisions based on the Gap Analysis data must be supported by ground-truthing and more detailed analyses. Because

Margaret Frisina photo

MFWP is currently using the "Sagebrush Land Cover-Montana" map as a tool for planning our purpose is to contribute to improved accuracy of the map.

Acknowledgments

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A comparison of winter elk use on 13 Montana winter ranges.

Michael R Frisina

Results from the statewide browse inventory indicate elk are impacting woody vegetation on a number of state-owned Wildlife Management Areas (WMA) (Knapp and Frisina 2001, Thompson 2002, Frisina and Knapp 2005). Current concern is that elk (*Cervus elaphus*) are negatively impacting rough fescue (*Festuca scabrella*) grasslands on the Sun River WMA (SN) (Quentin Kujala and Robert Harrington 2004, personal communication). Consequently, the Wildlife Division Administrator and the Habitat Bureau Chief asked me to compare the intensity of winter elk use on a number of Montana ranges.

Such a comparison is difficult due to the unique nature of each winter range, variations in weather patterns, and timing of seasonal migrations among elk populations. I developed an index of relative elk use for comparing areas. This approach should provide insight regarding perceived similarities and differences among Montana's elk winter ranges.

Methods

An index reflecting elk use in relation to time was created to compare winter ranges. The parameters used to compute an index include: number of elk, area of winter range, and length of time elk occupy the range.

Population Estimates

Because elk numbers and weather conditions vary over the winter, elk numbers used are estimates by MFWP biologists. The number of elk on a winter range often varies by day, month, etc.; but for purposes of calculating an index, biologists were asked to provide an estimate of peak numbers on a particular WMA or ranch.

Winter Range Area

Acreages of WMAs from MFWP (2005) and the Yellowstone Northern Range (YNR) from Lemke et al. (1998) were used. Craig Jourdonnais provided the estimate of the Sun Ranch (SR) winter range. Robert Brannon provided the size estimate for the Spanish Q Ranch (SQ). The MFWP wildlife biologist responsible for management of each winter area was asked to estimate the percentage of total area available for elk use during winter months. For example, cliffs, rocky mountain peaks, steep rocky canyons, or areas above winter range were excluded. Because available acres of winter range varies by year, depending on weather, this estimate most accurately depicts area available during a mild winter as compared to a severe winter.

Elk Days Use

The same biologists also estimated the approximate number of months that elk are usually on the winter range in significant numbers. Timing of elk use varies and elk often make use of both the WMAs and adjacent lands simultaneously. These considerations were not addressed in index calculation. Each biologist was asked to produce a time estimate that reflects elk use of the WMA or ranch in question.

Index of Use

Each index of use was calculated as follows:

Area (acres) x Percentage of range available = Total acres available
Total acres available ÷ Number of elk = Acres per elk
Acres per elk ÷ months elk present = Elk use index

The smaller the index the greater the intensity of elk use. Indices for individual areas and parameters used in index calculation are summarized in Table 1.

Results and Discussion

Of 13 areas analyzed, DM (.4), and WL (.5) had the highest use intensity (Fig. 1). The YNR was used as a baseline for comparison with the SR, SQ and MFWP WMA's. The YNR is recognized by a number of authors as a winter range intensely used by elk and one in which the impacts on browse plants has been documented (Kay 1990, Wagner et al. 1995, Wambolt and Sherwood 1999, Alt and Frisina 2000, National Research Council 2002). Seven of the 10 WMAs have indices indicating a higher intensity of winter elk use than the YNR (Fleecer/Divide WMA, Fleecer/High Rye/Mount Haggin WMA, DM, Blacktail WMA (BT), WL, SN). DM is located within the YNR. The Gallatin WMA (G) and YNR had a similar use intensity, and the privately-owned SR with an index of 1.7 is more intensely used during winter than the YNR.

The index for the YNR was calculated using estimates made when the elk herd was at its peak (Lemke et al. 1998) to compare with elk winter use on the 10 WMAs and 2 ranches. The YNR is unique compared to the other areas in that it winters large numbers of bison (*Bison bison*) in addition to elk. At

Table 1. Comparison of winter elk use on 10 Montana Wildlife Management Areas, and the Sun Ranch, Spanish Q Ranch, and Yellowstone Northern Range.

Winter Range or Wildlife Management Area	Abbrev.	MDFWP Region	Area (WMA)	% WMA Used	Months on WMA	Acres Winter Elk Habitat	# Wintering Elk	Acres/Elk	Index
Fleecer/Divide	FD	3	5 391	100	5	5.391	1 000	5 4	1 1
FleecerHighRye/MtHaggin	FH/MH	3	58 457	80/10[1]	5	7 248	400	18 1	3 6
Dome Mountain	DM	3	4 950	90	4	4 455	2 500	1 8	0 4
Canyon Creek	CYN	3	2 210	100	3	2 210	200	11 1	3 7
Robb/Ledford	RL	3	28 078	90	5 7	25 270	800	31 6	5 5
Blacktail	BT	3	17 781	100	5 7	17 781	2 500	7 1	1 2
Bear Creek	B	3	3 458	60	1	2 075	250	8 3	8 3
Wall Creek	WL	3	7 067	85	5	6 007	2 600	2 3	0 5
Gallatin	G	3	8 611	60	5	5 167	400	12 9	2 6
Sun River	SN	4	20 600	75	6 5	15 450	2 308	6 7	1 0
Spanish Q Ranch (private)	SQ	3	13 000	70	5	9 100	400	22 8	4 6
Sun Ranch (private)	SR	3	25 000	100	5	25 000	3 000	8 3	1 7
Yellowstone Northern Range	YNR	3	377 163	85/93[2]	6 5	340 233	20 284[3]	16 8	2 6

[1]80% of the FleecerHigh Rye WMA was considered useable winter elk habitat 10% of the Mt Haggin WMA was considered useable winter elk habitat

[2]85% of the YNR was outside Yellowstone National Park was considered useable elk winter habitat 93% of the winter elk range within Yellowstone National Park was considered useable

[3]Represents northern herd at its highest recorded population peak in 1994 (Lemke et al 1998) plus 762 bison using the same range were factored in using a ratio of 1 bison equals 2 elk

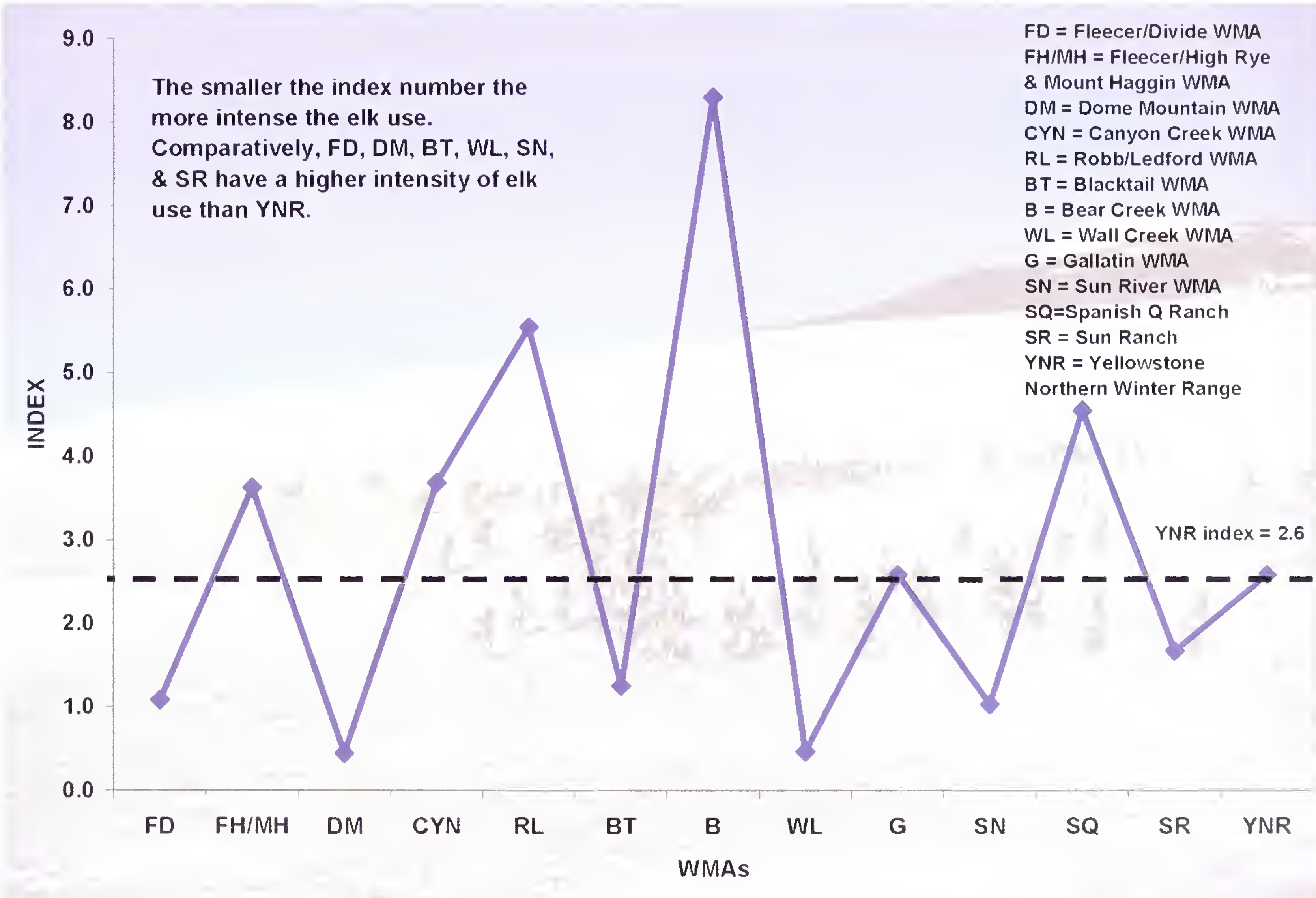

Figure 1. A graphic comparison of elk use on 10 Montana Wildlife Management Areas and 2 ranches with Yellowstone Northern Range

the YNR elk population peak in 1994, the winter population was estimated at 18,832 elk (Lemke et al. 1998). In 1994 about 762 bison inhabited the YNR (Thomas Lemke and Keith Aune personal communication). Bison are mostly grazers (Shaw 1996) while elk are more variable feeders consuming a combination of browse and herbaceous forage, depending on what is available (Kufeld 1973). Where browse is available, elk will consume it in amounts proportional to availability. For example, in a comparison of 8 Montana elk winter ranges, browse composition in the diet ranged from a high of 60-90% in the Flathead to a low of only trace amounts on the Moise Bison Range (Rognrud and Janson 1971). This same analysis reported browse as composing 23% of the elk winter diet in the Gallatin area (a much larger area than G), which is also associated with Yellowstone Park. The Mount Haggin WMA winter range, like the Gallatin and YNR, is composed of a mixture of palatable browse and herbaceous plants. Frisina and Wambolt (in review) found browse composed 56% of the elk winter diet on the Mount Haggin WMA. Because the YNR is a combination of browse and herbaceous vegetation there is likely competition between elk and bison for the herbaceous forage. Therefore it was necessary to incorporate bison into the index for the YNR. After comparing the average weight of elk and bison and considering diet overlap, 1 bison was equivalent to 2 elk for YNR index. Bison equivalents were added to the 1994 elk population estimate to come up with the 20,284 wintering elk in Table 1. The Canyon Creek WMA (CYN), Robb/Ledford WMA (RL), Bear Cr. WMA (B), and the SQ all had relatively high index numbers or relatively low elk winter densities.

Conclusions

The index system presented here may be useful for prioritizing WMAs by MFWP for vegetation monitoring. Those WMAs with indices indicating elk use is more intense than the YNR should be priority areas for applying browse evaluation techniques (Keigley and Frisina 1998) and other MFWP vegetation monitoring protocols (Harrington 2005)

Acknowledgements

Thomas Lemke and Keith Aune provided population estimates for elk and bison and their use of the YNR and DM. Craig Jourdonnais provided estimates for the WL, G, and B and the privately owned SR. Craig Fager provided estimates for BT, Mount Fleecer, and Mount Haggin WMAs, Gayle Joslin provided estimates for the CYN. Quentin Kujala provided estimates for the SN. Robert Brannon provided estimates for the RL and SQ. Keith Aune and Carl Wambolt provided advice on how to compare bison and elk use. Carl Wambolt peer reviewed the draft manuscript. Without their assistance this project would not have been possible.

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Status of Browse on the Cowell Conservation Easement (R6)

Michael R. Frisina and Mark G. Sullivan

The Cowell Conservation Easement (CCE) was purchased by Montana Fish, Wildlife and Parks (MFWP) in 2001. The easement consists of 4,489 acres that is integrated with an additional 5,285 acres of Bureau of Land Management and 640 acres of State School Trust lands (Sullivan 2005). The primary purpose of the easement is to protect sagebrush grassland and riparian habitats adjacent to the Missouri River Breaks (MFWP 2004). The CCE and associated lands have a long history of livestock grazing and providing habitat for a variety of wildlife. Species using the CCE include mule deer (*Odocoileus hemionus*), antelope (*Antilocapra americana*), elk (*Cervus elaphus*), sharp-tailed grouse (*Tympanuchus phaisianellus*), and at times 75-100 sage-grouse (*Centrocercus urophasianus*) (Sullivan 2004). Additionally, a variety of non-game and small game wildlife occur throughout the CCE. A stipulation of the easement required improved grazing management through application of rest-rotation concepts as described by Hormay (1970), Egan (2003), and MFWP (2004). The rest rotation grazing system was initiated in 2003 and all range improvements, necessary to implement the grazing plan, have been accomplished.

As part of MFWP monitoring efforts, we were asked in 2001 to initiate field surveys to determine the status of browse on the CCE. Browse evaluation on the CCE is a continuing process. Our purpose is to summarize here work accomplished through 2005 and the report is intended to compliment and will eventually be synthesized with the vegetation data reported by Lane (2004). Lane's project was in cooperation with the Montana State University Department of Animal and Range Sciences and the August L. Hormay Memorial Scholarship fund. The work by Lane (2004) emphasized the collection of baseline data at 4 range exclosures (3 livestock and 1 wildlife & livestock) proposed in 2002 (Frisina 2002) and constructed in 2003 (Sullivan 2004). Our work emphasizes application of browse architecture techniques described by Keigley and Frisina (1998) to determine browsing intensity. Our work and that by Lane (2004) will aid in monitoring use by cattle and large wild ungulates on the CCE. Additionally, Taylor and Taylor (2001) completed a vegetation survey of the CCE.

METHODS

At 4 sites on the CCE 20 individual plants for each dominate woody species were categorized into one of the 4 plant architectures (uninterrupted, retrogressed, arrested, released) described by Keigley and Frisina (1998). A total of 140 plants were measured at the 4 sites (Tables 1 and 2).

RESULTS AND DISCUSSION

All of the 4 taxa measured were intensely browsed (Table 2). Chokecherry (*Prunus virginiana*) was measured at all 4 sites since it is one of the more common browse plants on the CCE. The arrested and retrogressed architectures are typical of plants with a history of intense browsing, while the uninterrupted growth form is indicative of light to moderately browsed plants (Keigley and Frisina 1998). Browsing intensity of chokecherry was 100% at 3 sites and 95% at 1 site (Table 2). Browsing intensity for black hawthorne (*Crataegus douglasii*), silver buffaloberry (*Shepherdia argentea*), and serviceberry (*Amelanchier alnifolia*) was 100, 80, and 100 percent respectively (Table 2).

CONCLUSIONS

The intensity of browsing upon chokecherry, silver buffaloberry, service berry and black hawthorne is threatening the long term survival of these taxa on the CCE. The extent to which the intense browsing can be attributed to cattle or wildlife is unclear at this time. Future monitoring should focus on this issue by periodically repeating measurements at the 4 study sites and transects established by Lane (2004) at the exclosures. Also, monitoring use on browse species during the rest and deferred livestock grazing treatments (MFWP 2004) should, over time, provide insight at to the influence of cattle and wildlife on browse plants. Since the grazing system was recently implemented (Sullivan 2004) and the CCE has received continuous season long livestock grazing for many years, it might take several years to document any changes in woody vegetation resulting from the rest-rotation grazing system. The creation of additional

Table 1. Descriptions of 4 browse evaluation sample sites established on the Cowell Easement (R6) during 2001 & 2002.

Sample Site Number	Date Established	Location	GPS Coordinates	Taxa Measured	Notes
1	10/10/01	Killwoman Cr.	N47.73945 W107.53273	Black Hawthorne Chokecherry	Older hawthorne is about 10 ft. tall, mid-sized hawthorne is about 7 ft. tall, shortest hawthorne is 20-24 in. All chokecherry was 20-24 in. tall. Small amounts of snowberry and skunkbrush are also present.
2	10/10/01	North Fork Killwoman Cr.	N47.74245 W107.54437	Silver Buffaloberry	Older buffaloberry was about 7 ft. tall, mid-sized buffaloberry was about 20 in. tall, shortest hawthorne was 6-8 in. tall. Chokecherry height was not measured and there is a small amount of smooth currant at this site.
3	10/11/01	North Fork Killwoman Cr	N47.74021 W107.55489	Chokecherry	Tallest chokecherry was about 20 in. Some 2 yr. and 1 yr. stems were observed.
4	10/11/01 & 8/27/02	Armstrong1	N47.72279 W107.51299	Chokecherry Serviceberry	Tallest chokecherry 6 ft., mid-size 3 ft., shortest less than 20 in.Tallest serviceberry 6 ft. with the occasional plant 12 ft., mid-size 3 ft., shortest less than 20 in. Buffaloberry, hawthorne, chokecherry, dogwood, snowberry, skunkbrush, currants, juniper also present in this area.

Table 2. Browsing intensity data at 4 sample sites on the Cowell Easement (R6).

Sample Site (N=20 for each taxon at each site.)	Chokecherry	Black Hawthorne	Silver Buffaloberry	Serviceberry	Browsing Level
1-10/10/01	95% arrested[1] 5% retrogressed	95% arrested 5% uninterrupted			Intense
2-10/10/01	75% arrested 20% retrogressed 5% uninterrupted		75% arrested 5% retrogressed		Intense
3-10/11/01	95% arrested 5% uninterrupted				Intense
4-8/27/02	95% arrested 5% uninterrupted			100% arrested	Intense

[1]Architecture types as described by Keigley and Frisina (1998)

Mike Frisina photo

monitoring sites on the CCE should be considered to better determine the extent of browsing across the entire landscape.

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Status of browse on the Ear Mountain WMA (R4)

Michael R. Frisina and Quentin J. Kujala

In 1998 we began an analysis of livestock grazing on the Ear Mountain Wildlife Management Area (EMWMA) (Frisina and Kujala 1999 and Frisina and Kujala 2001) to address concerns that shrubs on the area may be negatively impacted by intense browsing. We analyzed the influence of the grazing system for cattle that was in place since 1991 and also considered the potential for over-browsing by wildlife (Frisina and Kujala 1999). To accommodate livestock grazing, the WMA was divided in to 2 pastures (South Pasture and North Pasture). The grazing strategies for the 2 pastures were described in detail by Frisina and Kujala (1999) and Frisina and Kujala (2001). Techniques described by Keigley and Frisina (1998) were used to determine the status of browse on EMWMA.

In the South Pasture browse use was determined to be intensive, but herbaceous vegetation appeared to be maintaining its health and vigor (Frisina and Kujala 1999). In the North Pasture browse use was also determined to be intensive; soil compaction was noted in cattle travel routes. Intensive grazing use at water locations and other places where cattle congregate was noted (Frisina and Kujala 2001). Initially we suspected cattle were responsible for most of the intense browse use, but as the situation was further studied it became apparent that mule deer (*Odocoileus hemionus*) may also be intensively browsing some areas during winter. This became apparent at sites that had been rested from livestock grazing yet still showed signs of intensive browsing. To address the influence of cattle use on browse plants at MWMA adjustments were made to the grazing system in 2000 and 2001 that increased the amount of growing season rest from cattle grazing. The stocking rate was also adjusted to levels that we considered better suited to the landscape and objectives for the MWMA (Frisina and Kujala 1999, Frisina and Kujala 2001). We also decided to continue monitoring the status of browse plants to determine the contribution of wildlife to the intense browsing. Monitoring will also be used to determine if additional adjustments

Table 1. Bebb willow (*Salix bebbiana*) growth rates, Ear Mountain WMA South Pasture, 1986-2004.

Year	Livestock Grazing Treatment (Frisina and Kujala 1999)	AUMS	Net Growth cm/year, n=20, (growth left after browsing through growth period includes winter wildlife use)	Growth Prior to Winter cm/year, n=20, (Includes some summer use by wildlife and cattle)
1986	Rest	0	43 (5yr. avg.)	-
1987	Rest	0	43 (5yr. avg.)	-
1988	Rest	0	43 (5yr. avg.)	-
1989	Rest	0	43 (5yr. avg.)	-
1990	Rest	0	43 (5yr. avg.)	-
1991	June	885	18 (5yr. avg.)	-
1992	August	400	18 (5yr. avg.)	-
1993	August	448	18 (5yr. avg.)	-
1994	Rest	0	18 (5yr. avg.)	-
1995	June	530	18 (5yr. avg.)	-
1996	August	200	26	-
1997	August	179	14	-
1998	Rest	0	23	12
1999	June	368	9	-
2000	August	293	26	-
2001	Rest	0	20	-
2002	June	391	9	13
2003	August	325	-	12
2004	Rest	0	-	16
2005	June	381	-	-

Table 2. Chokecherry growth rates, Ear Mountain WMA North Pasture, 1999-2004.

Year	Livestock Grazing Treatment (Frisina and Kujala 1999)	AUMS	Net Growth cm/year, n=20, (growth left after browsing through growth period includes winter wildlife use)	Growth Prior to Winter cm/year, n=20, (Includes some summer use by wildlife and cattle)
1999	Rest	0	9	-
2000	June (Sept Fire Event)	43.2	7	-
2001	August	70	-	-
2002	Rest	0	20	-
2003	June	52.5	-	9
2004	August	69.5	-	8
2005	Rest	0	-	-

Table 3. Cottonwood growth rates, Ear Mountain WMA North Pasture, 2004.

Year	Livestock Grazing Treatment (Frisina and Kujala 1999)	AUMS	Net Growth cm/year, n=20, (growth left after browsing through growth period includes winter wildlife use)	Growth Prior to Winter cm/year, n=20, (Includes some summer use by wildlife and cattle)
2004	August	69.5	-	20
2005	Rest	0	-	-

in livestock grazing are necessary. Here we summarize data collected since 1999 at 3 monitoring sites on the EMWMA (Tables 1, 2, and 3).

Literature Cited

Frisina, M. R. and Q. Kujala. 1999. South pasture – Ear Mountain Wildlife Management Area. Livestock grazing analysis. Montana Fish, Wildlife and Parks. Helena, Montana.

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Artemisia tridentata tridentata
Mule Deer
Populus spp.
Bighorn
Salix spp.
Moose
KODACHROME
MADE IN USA
Cercocarpus ledifolius
Bighorn ewe
Chrysothamnus nauseosis
Ewe
Rosa spp.
Mule Deer Fawn